4.9 Effects of the Alternatives on the Ecosystem

In this section the principles and policies of ecosystem-based management are outlined and how present groundfish fishery management meets the objectives of ecosystem-based management is summarized. It will be clear from this evaluation that ecosystem-based management encompasses a variety of objectives that overlap all alternatives, particularly the consideration of other ecosystem components–marine mammals and sea birds or non-target species in–fishery management decisions (Alternatives 2.1, 2.2, 4.1, and 4.2), conservative single-species management (Alternative 3), fish habitat protection (Alternative 5), and fishing capacity and fishing rights issues (Alternatives 6.1 and 6.2). Because of this overlap, those issues and impacts are not analyzed when evaluating how well each alternative meets the objectives of ecosystem-based management. Instead, how the various alternatives perform with respect to various ecosystem-level measures that might indicate the impacts of the alternatives from a broader ecological viewpoint are presented in Section 4.9.2. In Section 4.9.3 the ecosystem-level ecological impacts are summarized and how each alternative performs with respect to ecosystem-based management is discussed.

4.9.1 Principles and Policies of Ecosystem-Based Management

Fish are only one component of a complex marine ecosystem. Removing fish for human consumption can potentially have broad impacts to the marine ecosystem unless safeguards are incorporated into fishery management plans. Fisheries can impact ecosystems in numerous ways. Populations of fish and other ecosystem components can be affected by the selectivity, magnitude, timing, location, and methods of fish removals. Fisheries can also impact ecosystems by vessel disturbance, nutrient cycling, introduction of exotic species, pollution, unobserved mortality, and habitat alteration.

Ecosystem-based management strategies for fisheries are being developed around the world to address the larger impacts due to fishing. Ecosystem-based fishery management aims at conserving the structure and function of marine ecosystems, in addition to conserving fishery resources. An ecosystem-based management strategy for marine fisheries is one that minimizes potential impacts while at the same time allowing the extraction of fish resources at levels sustainable for both the fish stock and the ecosystem.

The Sustainable Fisheries Act (SFA) of 1996 strengthened the Magnuson-Stevens Fishery Conservation and Management Act (the Magnuson-Stevens Act) by mandating new conservation measures. One provision of the SFA was the appointment of a NMFS Ecosystem Principles Advisory Panel (the Panel). The panel was tasked to report to Congress on the extent to which ecosystem principles are applied in fishery conservation and management, including research, and propose actions that should be undertaken to expand the application of ecosystem principles in fishery conservation and management. The panel's report was recently published, and thus provides updated information on ecosystem-based management of fisheries (Ecosystem Principles Advisory Panel 1999). The panel described ecosystem-based management for marine fisheries:

> Ecosystem-based management can be an important complement to existing fisheries management approaches. When fishery managers understand the complex ecological and socioeconomic environments in which fish and fisheries exist, they may be able to anticipate the effects that fishery management will have on the ecosystem and the effects that ecosystem change will have on fisheries. However ecosystem-based management cannot resolve all of the underlying problems of the existing fisheries management regimes. Absent the political will to stop overfishing, protect habitat, and support expanded research and monitoring programs, an ecosystem-based approach cannot be effective.
>
> A comprehensive ecosystem-based fisheries management approach would require managers to consider all interactions that a target fish stock has with predators, competitors, and prey

species; the effects of weather and climate on fisheries biology and ecology; the complex interactions between fishes and their habitat; and the effects of fishing on fish stocks and their habitat. However, the approach need not be endlessly complicated. An initial step may require only that managers consider how the harvesting of one species might impact other species in the ecosystem. Fishery management decisions made at this level of understanding can prevent significant and potentially irreversible changes in marine ecosystems caused by fishing.

The panel developed a list of basic ecosystem principles and policies, and recommended that fisheries ecosystem plans (FEP) be developed as a first step toward a full ecosystem approach. Components of the plan include food web models, habitat needs, estimates of total removals, an assessment of uncertainty and buffers, indices of ecosystem health and use, long-term monitoring plans, and an assessment of other elements. The principles the panel developed are as follows:

- The ability to predict ecosystem behavior is limited.

- Ecosystems have real thresholds and limits which, when exceeded, can effect major system restructuring.

- Once thresholds and limits have been exceeded, changes can be irreversible.

- Diversity is important to ecosystem functioning.

- Multiple scales interact within and among ecosystems.

- Components of ecosystems are linked.

- Ecosystem boundaries are linked.

- Ecosystems change with time.

Basically, these basic principles outline the complex and dynamic nature of marine systems that are composed of interconnected groups of living organisms and their habitats. These basic principles form the foundation of ecosystem based management strategies.

Building on these principles, the panel developed several general ecosystem-based management policies to guide fishery managers. These policies reflect the overriding aspects of the principles associated with the limitations on extraction, uncertainty, and the role of humans within ecosystems. These six policies provided by the panel are as follows:

1. *Change the burden of proof.* We live in a world where humans are an important component of almost all ecosystems. Thus, it is reasonable to assume that human activities will impact ecosystems. The modus operandi for fisheries management should change from traditional mode of restricting fishing activity only after it has demonstrated an unacceptable impact, to a future mode of only allowing fishing activity that can be reasonably expected to operate without unacceptable impacts.

2. *Apply the precautionary approach.* The precautionary approach is a key element of the United Nations Agreement for Straddling Stocks and Highly Migratory Species (United Nations 1997) and the Food and Agriculture Organization of the United Nations (FAO) Code of Conduct for the Responsible Fisheries (FAO 1995). The U.S. is a signatory of both.

3. *Purchase "insurance" against unforseen, adverse ecosystem impacts.* Even under the precautionary approach, there is a risk of unforseen, adverse impacts on ecosystems. Insurance can be used to mitigate these impacts if and when they occur.

4. *Learn from management experiences.* Management actions and policies can be considered as experiments and should be based upon hypotheses about the ecosystem response. This requires close monitoring of results to determine to what extent the hypotheses are supported.

5. *Make local incentives compatible with global goals.* Changing human behavior is most easily accomplished by changing the local incentives to be consistent with broader social goals. The lack of consistency between local incentives and global goals is the root cause of many "social traps," including those in fisheries management (Constanza 1987). Changing incentives is complex and must be accomplished in culturally appropriate ways.

6. *Promote participation, fairness, and equity in policy and management.* Ecosystem approaches to management rely on the participation, understanding and support of multiple constituencies. Policies that are developed and implemented with the full participation and consideration of all stakeholders, including the interests of future generations, are more likely to be fair and equitable, and to be perceived as such.

The panel's overall recommendation was to expand the application of ecosystem principles, goals, and policies to fishery management and research. The mechanism to accomplish this is developing an FEP for each major ecosystem. The objectives of an FEP would be to provide the North Pacific Fisheries Management Council (the Council) and public with a description and understanding of the fundamental physical, biological, and human/institutional context of ecosystems, as well as to provide some direction on how this information can be used to set policies for ecosystem-based management options. Actions required to develop an FEP include characterization of the ecosystem, food web modeling, habitat needs, total removal calculations, assessment of uncertainty, indices of ecosystem health, long-term monitoring data, and an assessment of ecological, human and institutional elements of the ecosystem that are affected by fisheries.

A requirement for regional councils to develop FEPs is being considered for the next round of Magnuson-Stevens Act amendments. The annual ecosystem considerations chapter to the Stock Assessment and Fishery Evaluation Report (SAFE), together with what is provided in this draft programmatic SEIS, already assembles most of the information required for a FEP, so the job for the Council may not be as daunting a task as for other regional councils.

4.9.1.1 Evaluation of Alternative 1 Relative to Ecosystem-Based Management Standards

In 1999, the National Research Council (NRC), an agency organized by the National Academy of Sciences, set out new performance standards for fishery management in *Sustaining Marine Fisheries* (National Research Council 1999c). The publication reviews the status of global fisheries, the problems facing fishery managers, and provides recommendations on how to improve management to achieve sustainable marine fisheries. The NRC's overall recommendation was adoption of an ecosystem-based approach for fishery management with the goal "to rebuild and sustain populations, species, biological communities, and marine ecosystems at high levels of productivity and biological diversity, so as not to jeopardize a wide range of goods and services from marine ecosystems, while providing food, revenue, and recreation for humans" (National Research Council 1999c). To achieve an ecosystem-based approach, the NRC made eight specific recommendations:

1. Adopt conservative harvest levels for single species fisheries.

2. Incorporate ecosystem considerations into fishery management decisions.

3. Adopt a precautionary approach to deal with uncertainty.

4. Reduce excess fishing capacity and define and assign fishing rights.

5. Establish marine protected areas as a buffer for uncertainty.

6. Include bycatch mortality in TAC accounting.

7. Develop institutions to achieve goals.

8. Conduct more research on structure and function of marine ecosystems.

Although the NMFS is still evaluating the recommendations from the various ecosystem-based management review panels to determine how best to integrate them into the fishery management regime, the NRC recommendations provide one set of standards from which to evaluate the current management program for groundfish fisheries. For each recommendation, the NRC's summary recommendation is provided verbatum. A description of how current measures address these recommendations, and a brief evaluation of their effectiveness, is also provided.

> **Conservative Single Species Management.** Managing single-species fisheries with an explicitly conservative, risk-averse approach should be a first step toward achieving sustainable marine fisheries. The precautionary approach should apply. A moderate level of exploitation might be a better goal for fisheries than full exploitation, because fishing at levels believed to provide the maximum long-term yield tends to lead to overexploitation. Many species are overfished and their productive potential is impaired, even without considering the ecosystem effects of fishing for them. Expanding fisheries to include previously unfished or lightly fished species, such as deep-sea species, is unlikely to lead to large, sustainable increases in marine capture fisheries. Therefore, the committee recommends that management agencies adopt regulations and polices that strongly favor conservative and precautionary management and that penalize overfishing, as called for in the Magnuson-Stevens Fishery Conservation and Management Act of 1976 and the 1996 amendments to that Act, often referred to as the Sustainable Fisheries Act of 1996 (National Research Council 1999c).

The management of fisheries in the North Pacific is conservative, by comparison with other fisheries worldwide. Low harvest rates, combined with other management elements, provide for the following elements to achieve sustainable groundfish fisheries in the North Pacific:

- peer-reviewed scientific advice
- defined overfishing levels
- conservative harvest rates
- comprehensive observer coverage
- complete catch reporting

All groundfish stocks are considered relatively healthy after 20 years of sustained annual harvests of about 2 million mt. No fish stocks have been deemed overfished, approaching an overfished condition, or subject to overfishing in a recent evaluation of the status of U.S. fisheries (NMFS 1998o). The components of conservative single species management for the North Pacific groundfish fisheries are described below:

- *The intended catch is well below the absolute catch limit.* Total removals of groundfish are controlled by annual catch limits established for each stock. For each target stock, three harvest levels are set, corresponding to the overfishing level (OFL), the acceptable biological catch (ABC), and total allowable catch (TAC). TACs are annual catch limits for the fishery, and are established at or below the ABC. ABCs define acceptable harvest levels from a biological perspective, and the defines the unacceptable harvest level. To further minimize the possibility of catches jeopardizing a stock's long-term productivity, there is a buffer established between ABC and OFL.

- *Harvest rate specifications are more conservative when less information is available.* A precautionary approach is used to address uncertainty around parameters used in stock assessments. The maximum allowable rates are prescribed in descending order of preference, corresponding to descending order of information availability (Thompson 1996). Additionally, maximum sustainable yield (MSY) is treated as a limit, rather than a target. For most stocks, ABC is based on a rate less than or equal to $F_{40\%}$, which is the fishing mortality rate associated with an equilibrium level of spawning per recruit equal to 40 percent of the equilibrium level of spawning per recruit in the absence of any fishing. In other cases where less information is available about the stock, ABC is generally based on the three-fourths of the natural mortality rate (M). Both the $F_{40\%}$, and $0.75M$ rates are considered to be conservative harvest rates for most groundfish stocks (Clark 1993; Rosenberg and Restrepo 1996). For most stocks OFL is defined based on $F_{35\%}$. The conservative nature of our tier system is fully discussed in Section 2.7 and referenced throughout Section 4.4.

- *Harvest rates are reduced at lower than average stock size levels, thereby allowing rebuilding.* If the biomass of any stock falls below B_{MSY} or $B_{40\%}$, (the long-term average biomass that would be expected under average recruitment and $F = F_{40\%}$,), the fishing mortality rate is adjusted relative to stock status. This serves as an implicit rebuilding plan should a stock fall below a reasonable abundance level. The conservative nature of the tier system is fully discussed in Section 2.7 and referenced throughout Section 4.4.

- *The optimum yield limit adds additional precaution.* Since 1981, the total annual allowable catch of Bering Sea/Aleutian Islands (BSAI) groundfish must be less than the optimum yield (OY) upper limit of 2 million mt. This has limited the sum of TACs for all species to 2 million mt per year, considerably less than the sum of all ABCs. In some years, ABCs have totaled more than 2.8 million mt. As a result, many groundfish stocks, particularly flatfish stocks, have been exploited well below sustainable levels (Witherell 1995). The conservative nature of the tier system is fully discussed in Section 2.7 and referenced throughout Section 4.4.

- *Monitoring allows catches to stay within specified levels.* All fish caught in any fishery (including bycatch), whether landed or discarded, are counted toward the TAC for that stock. Based on comprehensive onboard observer data and reports provided by the fleet, directed fisheries for each species or complex are closed before the TAC is reached, so that catches are maintained within biologically acceptable levels. Observer data provides for accurate and precise estimation of Alaska groundfish catch (Volstad et al. 1997).

Evaluation

Existing single-species management of North Pacific groundfish meet the conservative and risk averse approach standard recommended by the NRC. None of the groundish stocks are subject to overfishing as defined under the Magnuson-Stevens Act. However, we have insufficient information on some stocks to determine if they are being overfished. Improvements can be made in our single-species management and these have been outlined in our target and non-target species alternatives (Section 4.1.2 and 4.1.3).

Incorporating Ecosystem Considerations into Fishery Management. Fishery management should take account of known and probable goods and services of marine ecosystems that are potentially jeopardized by fishing. The aim is to sustain the capacity of ecosystems to produce goods and services at local to global scales and to provide equitable consideration of the rights and needs of all beneficiaries and users of ecosystem goods and services (National Research Council 1999c).

The Council has been actively developing an ecosystem-based approach to managing fisheries (Table 4.9-1). The Council's approach involves public participation, reliance on scientific research and advice, conservative catch quotas, comprehensive monitoring and enforcement, bycatch controls, gear restrictions, temporal and spatial distribution of fisheries, habitat conservation areas, and other biological and socioeconomic considerations. Management measures are also taken to minimize potential impacts of fishing on seafloor habitat and other ecosystem components such as marine mammals and seabirds.

Table 4.9-1 North Pacific Fishery Management Council Goals and Objectives for Ecosystem-Based Management

Definition: Ecosystem-based management, as defined by the NPFMC, is a strategy to regulate human activity toward maintaining long-term system sustainability (within the range of natural variability as we understand it) of the North Pacific, covering the Gulf of Alaska, the Eastern and Western Bering Sea, and the Aleutian Islands region.

Objective: Provide future generations the opportunities and resources we enjoy today.

Goals:
1. Maintain biodiversity consistent with natural evolutionary and ecological processes, including dynamic change and variability.
2. Maintain and restore habitats essential for fish and their prey.
3. Maintain system sustainability and sustainable yields of resources for human consumption and non-extractive uses.
4. Maintain the concept that humans are components of the ecosystem.

Guidelines:
1. Integrate ecosystem-based management through interactive partnerships with other agencies, stakeholders, and public.
2. Utilize sound ecological models as an aid in understanding the structure, function, and dynamics of the ecosystem.
3. Utilize research and monitoring to test ecosystem approaches.
4. Use precaution when faced with uncertainties to minimize risk; management decisions should err on the side of resource conservation.

Understanding:
1. Uncontrolled human population growth and consequent demand for resources are inconsistent with resource sustainability.
2. Ecosystem-based management requires time scales that transcend human lifetimes.
3. Ecosystems are open, interconnected, complex, and dynamic; they transcend management boundaries.

The public, scientists, and policy makers have all contributed to development of an ecosystem-based management strategy. Since 1995, the groundfish plan teams have added an "Ecosystem Considerations" section to their SAFE document (e.g., NPFMC 1998f) that provides an annual assessment of the ecosystem, review of recent ecosystem-based management literature, updates of ongoing ecosystem research, local observations from coastal residents and fishermen, and any new information on the status of seabirds, marine mammals, habitat and other components of the North Pacific ecosystem. The Council also has an Ecosystem Committee, which was established to discuss and recommend possible approaches to incorporating ecosystem concerns into the fishery management process. A major role of this committee has been to provide the Council and stakeholders with information on ecosystem-based fishery management in the North Pacific Ocean. While a full understanding of North Pacific ecosystem dynamics remains beyond our grasp, the Council and NMFS are striving to achieve a better understanding of this system and, in the interim, are attempting to incorporate what we do know in the fisheries management process.

<u>Evaluation</u>

The NRC advocates ecosystem-based fishery management to achieve sustainability of fish resources. Nevertheless, because ecosystem-based management is difficult to define, and as yet, there are no real world examples where it has been specifically applied, the NRC tried instead to lay out elements of an ecosystem approach. These elements include ecosystem monitoring, monitoring of human systems, application of ecosystem principles, cross-sectoral institutional arrangements, large marine ecosystem approach, and a precautionary approach. All these elements are applied to management and research of North Pacific fisheries.

However, improvements can be made in all these areas. We are still challenged to move towards a system that explicitly acknowledges ecosystem-based management goals in our quantitative assessment procedures.

> **A Precautionary Approach to Deal with Uncertainty.** Fisheries are managed in an arena of uncertainty that includes an incomplete understanding of and ability to predict fish population dynamics, interactions among species, effects of environmental factors on fish population, and effects of human actions. Therefore, successful fishery management must incorporate and deal with uncertainties and errors. The committee recommends the adoption of a precautionary approach in case of uncertainty. Management should be risk-adverse. Although research and better information can reduce uncertainty to a degree, they can never eliminate it (NRC 1999c).

The primary sources of scientific uncertainty in fishery management are the uncertainty about fishing effects on ecosystems and the uncertainty associated with stock assessments. For stock assessments, uncertainty can be associated with catch statistics (e.g., observer estimation error, misreporting), biological parameters (e.g., maturity, mortality, growth), resource assessment survey measurement error, and natural variability in dynamics, such as recruitment.

In the North Pacific fishery management arena, uncertainty is dealt with in several ways. In the case of establishing acceptable harvest rates of fish, the ABCs are based on a system of tiers, corresponding to information availability on population dynamics parameters. The Pacific cod stock assessment went an additional step of evaluating uncertainty regarding specific model parameters. The ABC for the 2000 fisheries was based on a risk-averse optimization procedure that adjusts for uncertainty in the selectivity coefficients and natural mortality rate. This type of analysis will likely be expanded to other assessments in coming years.

Uncertainty regarding species interactions, environmental factors, and human actions are addressed with other management measures. Regulatory changes that have to some degree addressed these sources of uncertainty include establishment of marine protected areas, the OY limit, the forage fish prohibition, making corals and sponges prohibited species, spatial and temporal restrictions to reduce potential competition with marine mammals and seabirds.

Evaluation

The Ecosystem Principles Advisory Panel, in its report to Congress, noted that the Council has generally acted conservatively in the face of uncertainty (i.e., applying the precautionary approach) compared with the decisions of other regional fishery management councils (Ecosystem Principles Advisory Panel 1999).

> **Reducing Excess Fishing Capacity and Assignment of Fishing Rights.** Excess fishing capacity (fishing capacity is the ability to catch fish or fishing power) and overcapitalization (capitalization, related to capacity, is the amount of capital invested in fishing vessels and gear) reduce the economic efficiency of fisheries and usually are associated with overfishing. Sustainable global reductions in fishing capacity are of the highest priority to help reduce overfishing and to deal with uncertainty and unexpected events in fisheries. Overcapacity is difficult to manage directly, and usually evolves in management regimes that encourage unrestricted competition for limited fishery resources. Consequently, managers and policy makers should focus on developing or encouraging socio-economic and other management incentives that discourage overcapacity and that reward conservative and efficient use of marine resources and their ecosystems.
>
> At the core of today's overcapacity problem is the lack of, or ineffective, definition and assignment of rights in most fisheries. In addition, subsidies that circumvent market forces have contributed significantly to the overcapacity problem in many fisheries. Therefore, the committee recommends for many fisheries a management approach that includes the development and use of methods of allocation of exclusive shares of the fish resource or privileges and responsibilities (as opposed to open competition) and the elimination of subsidies that encourage overcapacity. A flexible and adaptive approach is essential, and careful attention must be given to equity issues associated with such approaches. The committee recommends experimental approaches to community-based fishery management, including the development of virtual communities. This would include research into the establishment of management groups in which participation is based on shared interests in a fishery and its associated ecosystem, with diminished emphasis on where participants live or their direct financial interests (NRC 1999c).

There is no doubt that the groundfish and crab fishing industries in the North Pacific are overcapitalized due to limited quotas and the race for fish. The NRC report (1999c) tends to link overcapacity with overfishing, because some fisheries (e.g., New England groundfish and scallops) have been traditionally managed with effort controls, rather than quotas. Because catch is limited by TACs and crab guideline harvest levels in the North Pacific, overcapacity does not necessarily increase the potential for overfishing. However, participants in overcapitalized fisheries can exert strong pressure for liberal catch quotas and other risk prone management measures, though there has been little evidence of that in fisheries under the Council's jurisdiction. Also, in extreme cases, excess harvesting capacity may shorten seasons to a point at which fishing quotas cannot be accurately monitored. The GOA pollock and BSAI crab fisheries are examples of fisheries in which quota overages have occurred in the North Pacific.

Overcapacity can also make it more difficult for managers to deal with unexpected events. This situation may be exacerbated when fishermen are limited to specific fisheries by licenses or endorsements. Fishermen have no place to use their vessels (and other not-so-liquid asset) when the stock is in lower abundance, the market drops, or unexpected events occur (e.g., Bristol Bay sockeye salmon fishery in 1997 to 1998). Often, the political response to these situations is subsidies, which further exacerbates the overcapacity situation. For fisheries to be sustainable and economically stable, capacity must be balanced with resource availability.

The Council has developed several programs to address overcapacity in the fisheries. Groundfish and crab management programs generally limit the number of vessels that are allowed to fish off Alaska. In addition, halibut and fixed-gear sablefish are managed under an individual fishing quota (IFQ) program, which does not limit the number of vessels, but instead grants permission to individuals to harvest a specified percentage of the TAC each year. Specific programs are reviewed below.

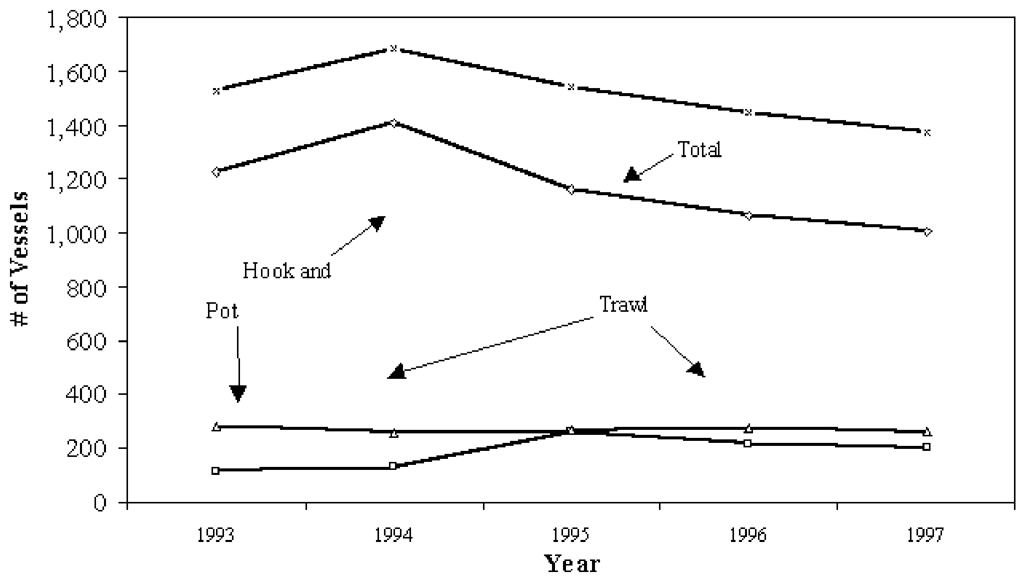


Figure 4.9-1 Trends in number of groundfish fishing vessels, that caught groundfish off Alaska 1993 to 1997.

A moratorium on new vessel entry into the federally managed groundfish and crab fisheries was implemented in 1996. The program is considered a placeholder, while more comprehensive management measures are developed. Currently the owners of 1,853 groundfish and 664 crab vessels hold moratorium fishing rights. In addition to limiting the number of vessels the moratorium also restricted each vessel's length.

Vessels that were less than 125 ft. length overall (LOA) may only be increased to 120 percent of their length on June 24, 1992, or up to 125 ft. LOA, whichever is less; vessels that are 125 ft. LOA or longer may not increase their length. Increasing a vessel's length could add harvesting capacity without increasing the number of vessels.

The License Limitation Program (LLP) for groundfish and crab vessels was implemented on January 1, 2000, and replaces the vessel moratorium. The original LLP, approved in 1995, was intended as the second step in fulfilling the Council's commitment to develop a comprehensive and rational management program for fisheries off Alaska. Amendments to that program approved in 1998 tighten the LLP and include additional restrictions on vessel numbers and fishery crossovers. Additional restrictions under development include an industry-funded license buyback program for the crab fisheries and further gear and species endorsement restrictions for the groundfish fisheries. Based on preliminary estimates of qualified vessels, the LLP should further reduce the number of vessels eligible to participate in the BSAI crab fisheries by more than 60 percent compared to the current vessel moratorium. The number of vessels predicted to be eligible for groundfish licenses (2,435) is greater than the number currently holding moratorium permits (Figure 4.9-1). However, the LLP carries stricter qualification standards, and many moratorium permits were never claimed). The LLP will be more restrictive in terms of areas a vessel can fish and types of gear it can deploy. It is also important to note that the vast majority of the vessels qualifying for the LLP are longline vessels less than 60 ft. LOA, and they are only eligible to participate in Gulf of Alaska, (GOA) fisheries. These vessels have typically had relatively small catch histories in past years.

The sablefish and halibut IFQ programs provide good examples of how the Council is working to control overcapacity in fisheries off Alaska. From 1975 to 1994 the central GOA halibut fishing seasons decreased from approximately 125 days to single day openings, while catches increased. Faced with very short seasons and increasing fishing effort, the Council passed an IFQ program for both the halibut and fixed-gear sablefish fisheries. These programs were initiated in 1995. After implementation, the fisheries changed from a short-pulse fishery to one that extends over several months. IFQs have allowed participants to better match fishing capacity with the amount of fish they are allowed to harvest during a year. In recent years the numbers of vessels and persons have declined, even as the TACs have been increasing.

The American Fisheries Act (AFA), passed in late 1998, among other things limited the number of harvesting and processing vessels that would be allowed to participate in the BSAI pollock fishery. Only harvesting and processing vessels that met specific requirements, based on their participation in the 1995–1997 fisheries will be eligible to harvest BSAI pollock. Preliminary estimates indicate that 21 catcher/processors and 120 catcher vessels qualify under the AFA. Nine large capacity catcher/processors were retired from the fishery by the AFA. Under the fishery cooperative structure now in place, not all 21 eligible catcher/processors fished during the 1999 late winter and early spring pollock seasons. The AFA also restricts eligible vessels from shifting their effort into other fisheries. *Sideboard* measures, as they have become known, prevent AFA eligible vessels from increasing their catch in other fisheries beyond their average 1995–1997 levels. Sideboard restrictions reduce the likelihood that the fishing capacity of AFA eligible vessels would be increased to better compete in those fisheries.

Evaluation

The NRC encourages the assignment of rights in most fisheries to address overcapacity. It recommends allocation of exclusive shares of the fish resource or privileges and responsibilities (as opposed to open competition) and the elimination of subsidies that encourage overcapacity. The IFQ program for halibut and sablefish fisheries, together with the multi-species community development quota (CDQ) program have proven successful at eliminating the race for fish, reducing capacity, and decreasing costs. Fishery co-ops, allowed for the BSAI pollock fleet under the AFA, appear to have done much the same for that fishery.

Alternatives to eliminate incentives for overcapacity should continue to be examined. The primary alternative to a competitive allocation process is share-based or rights-based allocation. These management systems provide incentives for members of industry to reduce overcapitalization voluntarily. Traditionally, regulations have been implemented to limit the growth of specific elements of fishing capacity (i.e., vessel length or horsepower). However, without the proper economic incentives, these types of restrictions have been circumvented and often proved to be ineffective in reducing fishing capacity.

> **Marine Protected Areas.** Where they have been used, marine protected areas, where fishing is prohibited, have often been effective in protecting and rebuilding ecosystems and populations of many (but not all) marine species. They often also lead to increases in the numbers of fish and other species in nearby waters. Importantly, they can provide a buffer against uncertainty, including management errors. Permanent marine protected areas should be established in appropriate locations adjacent to all the U.S. coasts. It will be important to include highly productive areas–that is, areas in which fishing is good or once was–if this management approach is to produce the greatest benefits.
>
> Protected areas will make the most effective contribution to the management of species and ecosystem when they are integrated into management plans that cover the full life cycles and geographic ranges of the species involved. Smaller, fixed protected areas will be most effective for species with life stages that are spent in close association with fixed topography in various stages of their lives. Wholly or largely pelagic species move according to ocean currents or other factors that are not necessarily related to fixed topographic structures and are thus likely to benefit less from small protected areas.

> The design and implementation of marine protected areas should involve fishermen to ensure that they believe the resulting systems will protect their long-term interests and to improve operational integrity. Because attempts to develop marine protected areas in the United States have been strongly opposed by some fishermen, the broad involvement of users is a key strategy. Current theory and experiences make clear that marine protected areas must be established over a significant portion of the fishing grounds to have significant benefits. Recent calls for protecting 20 percent of potential fishing areas provide a worthwhile reference point for future consideration, and emphasize the importance of greatly expanding the areas currently protected.
>
> Marine protected areas are not alternative to other techniques of fishery management and to the other recommendations in this report. They should be considered as only one of a suite of important ecosystem approaches to achieve sustainable fisheries and protect marine ecosystems. For marine protected areas to be most successful as fishery-management tools, their intended purposes must be clearly defined (NRC 1999c).

It has been long recognized that seafloor habitat is essential for maintaining productivity of fishery resources. Habitat that provides structural relief on an otherwise featureless bottom can be particularly important to fish for food, reproduction, and shelter from predators. Structural habitat includes boulders, corals, anemones, kelp, and other living organisms attached to the ocean bottom.

Because fishing gear can disturb structural habitat, areas where this habitat type are known to occur have been protected by regulations. Vast areas of the North Pacific have been permanently closed to groundfish trawling and scallop dredging to reduce potential adverse impacts on vulnerable and essential habitat and to protect juvenile crab. Other closures occur on a seasonal basis, and additional closures to mobile fishing gear are under consideration. A unique pair of nearshore pinnacles off Cape Edgecumbe in southeast Alaska has been designated as the Sitka Pinnacles Marine Reserve and closed to groundfish and halibut fishing with all gear types.

These marine protected areas comprise a relatively large portion of the continental shelf, and in many respects, serve as marine reserves (Figure 4.9-2). In the Bering Sea, habitat area closures encompass about 30,000 nm^2. To put this in perspective, this area is larger than Indiana or Maine and more than twice the size of Georges Bank off the east coast of the United States. The GOA closures encompass about 47,000 nm^2, but a vast majority (about 80 percent) of this closure area is off the continental shelf (greater than 200 nm). Some environmental advocates and scientists have suggested that marine reserves should be at least 20 percent of available habitat in order to be effective. The Bering Sea marine protection areas exceed this threshold by encompassing about 25 percent of the Bering Sea shelf areas where commercial quantities of groundfish could be taken with bottom trawl gear. Existing GOA closure areas encompass less than 10 percent of the trawlable shelf area (NMFS 1999e).

Evaluation

The NRC (1999c) considers permanent marine protected areas to be an important and useful tool for fisheries managers. Marine protected areas would provide a hedge against uncertainty, provide habitat protection, and allow for species and ecosystem protection.

The NRC defines marine protected areas as those where *all fishing* is prohibited. Furthermore, the NRC suggests that 20 percent of the potential fishing area be considered for marine protected areas. NRC states that these areas can lead to increases in the numbers of fish and other species in nearby waters. However, it remains to be seen whether these benefits would be realized in open access fisheries, which can increase effort adjacent to protected areas and potentially negate the gains.

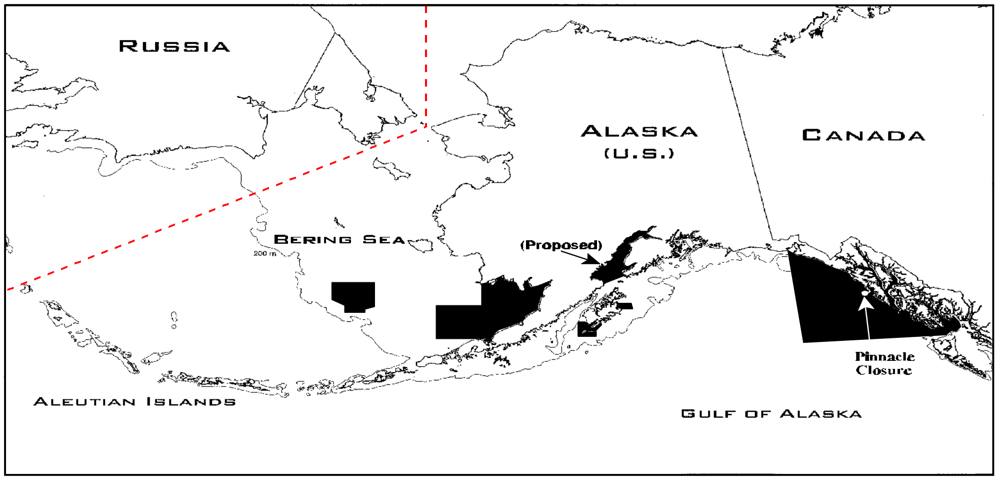


Figure 4.9-2 Year-round trawl closure areas established to protect fish and crab habitat. Source: NMFS

Existing no-trawl zones comprise a relatively large portion of the continental shelf. The three Bering Sea area closures (Pribilof Islands, Bristol Bay and Red King Crab Savings Area) total about 30,000 nm^2, which encompass about 25 percent of the Bering Sea shelf where commercial quantities of groundfish can be taken with bottom trawl gear. The GOA closures encompass about 47,000 nm^2, but a vast majority (about 80 percent) of this area is off the continental shelf (greater than 200 nm). Additional no trawl zones include the Steller sea lion rookeries and haulouts. The 2.5 nm^2 Sitka Pinnacles Marine Reserves, established in 2000, prohibits all groundfish and halibut fishing but allows recreational and commercial fishing for salmon.

Closing some productive areas to *all gear types* could be considered as an additional form of insurance. Habitat areas of particular concern (HAPCs), such as deep water coral reefs, could be evaluated for potential marine protected areas. The Council is reviewing an amendment that would set up a comprehensive, iterative approach for future HAPC identification and habitat protection. The approach would involve researchers, stakeholders, and management agencies. Meetings are planned in Sitka, Yakutat, and a location representing the western Aleutian Islands, in the fall of 2000 to discuss gorgonian coral protection measures.

Bycatch and Discards. Bycatch and discards add to fishing mortality and should be considered as part of fishing activities rather than only as side effects. Estimates of bycatch should be incorporated into fishery-management plans and should be taken into account in setting fishing quotas and in understanding and managing fishing to protect ecosystem and nonfished ecosystem components. Reducing fishing intensity on target species can reduce bycatch, often with no long-term reduction in sustainable yield. In some cases, technological developments and careful selection of fishing gear (e.g., bycatch-reduction devices) can be effective in reducing bycatch, and those options should encouraged, developed, and required where appropriate. More information is needed on discards and on bycatch and their fate (i.e., whether bycatch is retained or discarded and whether discards survive or die) (NRC 1999c).

The issues of bycatch and discards of fish resources stem from social, economic, and conservation concerns. From an ecosystem perspective, mortality of unwanted and prohibited species may reduce spawning potential, reduce biodiversity, alter regular paths of energy flow and balance, enhance the growth of scavenger populations, and add uncertainty to estimates of total removals.

The NRC raises conservation concerns for world fisheries where bycatch and discards are treated as side effects of fishing. Fortunately, however, in the North Pacific, this is not a problem. All bycatch and discarded groundfish are counted toward the TAC established for individual stocks that are presently managed. Additionally, because observers sample the entire catch, not just the retained portion, the information on bycatch and discards is available and is directly incorporated into the annual stock assessments of managed species.

Fish are discarded for two reasons: either because regulations require that they be thrown back (prohibited species), or they are unwanted for market reasons. Prohibited species are economically important non-groundfish species. Bycatch management measures implemented for groundfish fisheries of the eastern Bering Sea have aimed at reducing the incidental capture and injury of these economically important species traditionally harvested by other fisheries. These species include crab, herring, halibut, and salmon. Collectively, these species are called *prohibited species*, because they cannot be retained as bycatch in groundfish fisheries and must be discarded with a minimum of injury.

Bycatch controls on prohibited species were instituted on foreign groundfish fisheries prior to passage of the Magnuson-Stevens Act in 1976 and have become more restrictive in recent years (Witherell and Pautzke 1997). Bycatch limits are apportioned to specific groundfish target fisheries, and attainment of any apportionment closes that groundfish target fishery for the remainder of the season. Bycatch limits for 2000 BSAI groundfish trawl fisheries included 3,675 mt of halibut mortality, 1,853 mt of herring, 97,000 red king crabs, 3,350,000 bairdi Tanner crab, 4,350,000 opilio Tanner crab, 48,000 chinook salmon, and 42,000 other salmon. These limits equated to about 0.1 percent of the red king crab and opilio Tanner crab populations, 1 percent of the bairdi Tanner crab population, 1 percent of the herring biomass, and 1.5 percent of the halibut biomass. The impact of salmon bycatch on Alaska salmon populations remains unknown, but is thought to be less than 1 percent of the chum salmon population, and on the order of 2 percent to 4 percent of the adult chinook salmon population. To reduce the impact of bycatch on chinook salmon population, bycatch limits will be incrementally reduced to 29,000 chinook salmon by the year 2003.

In the North Pacific, discards of unwanted groundfish (so-called *economic discards*) result when fishermen do not have markets, sufficient equipment, time or the economic incentive to retain and process the catch. Section 313 of the Magnuson-Stevens Act require that the Council develop management measures to reduce the level of economic discards in the groundfish fisheries off Alaska. The Council adopted an improved retention and utilization (IR/IU) program for all groundfish target fisheries in order to reduce groundfish economic discards. It was implemented in 1998 under Amendments 49/49 to the FMPs. All discards of pollock and Pacific cod were prohibited under the program; only fish not fit for human consumption can be legally discarded. This measure has dramatically reduced overall discards of groundfish (Figure 4.9-3). For example, in 1997, about 22,100 mt of cod (8.6 percent of the cod catch) and 94,800 mt of pollock (8.2 percent of the pollock catch) were discarded. In 1998, discards amounted to only 4,300 mt of cod (2.2 percent) and 16,200 mt of pollock (1.6 percent). A regulation requiring full retention of all demersal shelf rockfish species (e.g., yellow-eye rockfish) was adopted in 1999.

The cod and pollock retention requirements of the IR/IU program are the first step. In 1999, with IR/IU in place, 125,500 mt of groundfish was discarded in the BSAI, or about 6.9 percent of the total groundfish there. In the GOA, the discard was 25,000 mt of groundfish, or 11 percent of the total GOA groundfish catch. Although these discard rates are much lower than most of the world's groundfish fisheries, which average about 19.9 percent discards, and although the discards are deducted from the TAC, the sheer volume of discards is still troublesome to many people who consider economic discards as waste of food and as having an unnecessary impact to the ecosystem. BSAI rock sole and yellowfin sole and GOA shallow water flatfish retention will be required beginning in 2003. The delay allows for development of new markets and

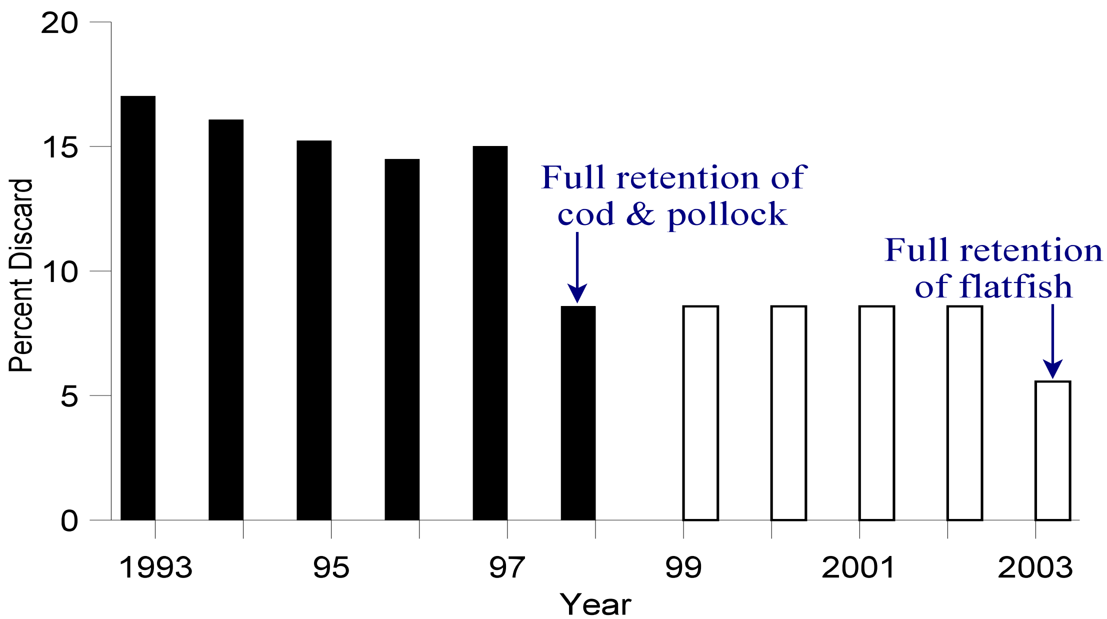


Figure 4.9-3 Total discard rates of Alaska groundfish, all areas and species combined, 1993–1998, with projections through 2003.

technological developments in gear by vessels engaged in these fisheries. These retention requirements are expected to reduce overall discard rates to about 5 percent.

In addition to bycatch limits, gear restrictions and other regulatory changes have also been implemented to reduce bycatch and waste. Biodegradable panels are required for pot gear to minimize waste associated with so-called ghost fishing of lost gear. Tunnel openings for pot gear are limited in size to reduce incidental catch of halibut and crabs. Giblets for groundfish have been prohibited to prevent ghost fishing and reduce bycatch of non-target species. With the implementation of an IFQ system for halibut and sablefish longline fisheries in 1995, bycatch and waste were reduced because the race for fish was eliminated, allowing for more selective fishing practices and significant reductions in actual gear deployment and loss. The emergence of fisherycooperatives in the BSAI pollock fishery in 1999 has also led to a reduction in bycatch through eliminating the economically wasteful race for fish. The discard rate of pollock in the offshore component of the fishery declined from about 2.4 percent to 0.5 percent in 1999 when pollock cooperatives were initiated in the BSAI. Under fishery cooperatives, vessels have an increased economic incentive to increase the utilization of their catch because they are no longer constrained by time. BSAI Amendment 57, finalized in 2000, prohibited the use of nonpelagic trawl gear for vessels targeting pollock in the Bering Sea, and concomitantly reduces allowable prohibited species bycatch of halibut and crabs.

Waste of salmon and halibut has been reduced by allowing bycatch of dead fish to be donated to food banks. The food banks in turn distribute the fish to needy people in the northwestern United States. Many fishing companies voluntarily participate in the donation program. Through 1998, over 3 million pounds of donated fish produced an estimated 12 million meals for needy persons.

A variety of other bycatch and discard reduction programs are currently under analysis or development, including proposals including gear research and bycatch reduction incentives, and a proposal for a nonpelagic trawl prohibition in Cook Inlet.

Evaluation

Numerous regulations have been implemented to reduce bycatch and discards of groundfish and crabs. It is unlikely that discarding can be significantly reduced below the 5 percent rate projected under current regulations, without requiring full retention of fish species unwanted for human consumption. In other words, a full retention requirement for sculpins and other species would likely result in less discards, but more fishmeal production. Bycatch and discard of crabs, halibut, and herring is a function of regulations. If full retention of all species was required, there would be virtually no bycatch or discard.

Institutions

Effective fishery management requires structures that incorporate diverse views without being compromised by endless negotiations or conflicts of interest. The committee recommends developing institutional structures that promote

- effective and equitable reduction of excess capacity,
- sustainable catches of targeted species,
- expansion of the focus of fishery management to include all sources of environmental degradation that affect fisheries,
- consideration of the effects of fishing on ecosystem,
- development and implementation of effective monitoring and enforcement, and
- the collection and exchange of vital data.

To achieve these goals, the spatial and temporal scales at which the institutional structures operate should better match those of important processes that affect fisheries. Participation in management should be extended to all parties with significant interests in marine ecosystems that contain exploited marine organisms. Institutions should allocate shares in or rights to fisheries, rather than allowing openly competitive allocations. The clear explication of management goals and objectives is a prerequisite to achieving effective and equitable management.

The Council is one of eight regional councils established by the Magnuson-Stevens Act to manage fisheries in the 200-mile Exclusive Economic Zone (EEZ). The Council primarily manages groundfish in the GOA and BSAI, including cod, pollock, flatfish, mackerel, sablefish, and rockfish species harvested mainly by trawlers, hook-and-line longliners, and pot fishermen. The Council also makes limited entry decisions for halibut, although the U.S.-Canada International Pacific Halibut Commission (IPHC) biologically manages the resource. Other large Alaska fisheries such as salmon, crab, and herring are managed primarily by the Alaska Department of Fish & Game (ADF&G). For a more detailed description of the Magnuson-Stevens Act and the regulatory process, refer to Section 2.7.8.

The Council has eleven voting members, six from Alaska, three from Washington State, one from Oregon, and a federal representative, the Alaska Regional Administrator of the NMFS. Voting members represent state fisheries agencies, industry, fishing communities, and academia. The Council's four nonvoting members represent the U.S. Coast Guard (USCG), U.S. Fish and Wildlife Service (USFWS) and Department of State, and the Pacific States Marine Fisheries Commission. The Council's staff of twelve resides in Anchorage, Alaska. The Council receives advice each meeting from a 23-member Advisory Panel (AP) representing user groups, environmentalists, recreational fishermen, and consumer groups, and from a 13-member Scientific and Statistical Committee (SSC) of highly respected scientists who review all information brought to the Council. For a more detailed description of the regulatory process, refer to Section 2.7.8.

Each Council decision is made by recorded vote in public forum after public comment. Final decisions then go to NMFS for a second review, public comment, and final approval. Decisions must conform with the Magnuson-Stevens Act, the National Environmental Protection Act (NEPA), Endangered Species Act (ESA), Marine Mammal Protection Act (MMPA), and other applicable laws including several executive orders. Regulatory changes may take up to a year or longer to implement, particularly if complex or contentious.

Evaluation

The Council has worked successfully to achieve the goal of sustainable fisheries. The structure of the Council's numerous committees (e.g., AP, SSC, Plan Teams, Ecosystem Committee) allows for incorporation of diverse views from interested parties. The Council coordinates activities with other institutions including the NMFS, IPHC, ADF&G, USFWS, USCG, and others. Individual stock assessment advice provided to the Council groups may also require broader participation from the scientific communities involved in protected species and essential fish habitat research, for example. This broader participation would lead to a comprehensive assessment process that explicitly takes ecosystem-based factors into account.

> **Information Needs -** Better understanding is needed for the structure and functioning of marine ecosystems, including the role of habitat and the factors affecting stability and resilience. This includes attempting to understand mechanisms at lower levels of organization (i.e., populations and communities), long-term research and monitoring programs, development of models that incorporate unobserved fishing mortality and environmental variability (e.g., El Niño events) into fishery models, multispecies models, and trophic models. More research is also needed on the biological effects of fishing, such as the alteration of gene pools and population structures as a consequence of fishing. More research is needed on the conditions under which marine protected areas are most effective, and marine protected areas themselves should be used as research tools as well as for conservation.
>
> More information is needed on the effects and effectiveness of various forms of rights-based management approaches and other management regimes, on the way people behave in response to different economic and social incentives, and on barriers to cooperation and sharing of information. The committee recommends research into the roles of communities in fisheries management, including the use of community-based quotas and other assignments of rights to communities, and explorations into the feasibility of granting management responsibilities to those engaged in a particular fishery, regardless of their geographic community ("virtual communities") (NRC 1999c).

While the fisheries in the North Pacific are managed with the best available science, there is an ongoing need to increase current understanding of the biological and socioeconomic factors in the fisheries. There is also a mandate to achieve some level of understanding of overall ecosystem dynamics and incorporate that understanding in our management approach. Each year, with input from its Groundfish and Crab Plan Teams and its SSC, the Council compiles and forwards to NMFS a list of research priorities in six specific areas of study:

1. Stock Assessments
2. Stock Surveys
3. Ecosystem Studies
4. Socioeconomic Research
5. Bycatch Reduction and
6. Fishery Monitoring

Each general study area contains numerous specific research recommendations aimed either at strengthening basic biological understanding of specific fish species; embracing the concept of ecosystem management and responding accordingly; gaining better knowledge of the impacts of allocation decisions; or improving the system of monitoring fishery removals and associated impacts.

Specific examples of current high priority research needs include the following:

- Continuing research on pollock stock structure, including impacts to the overall resource from removals in the transboundary area between the U.S. and Russia.
- Identification of the origin of chum and chinook salmon bycatch in the groundfish fisheries.
- Methodologies for incorporating uncertainty in stock assessments.
- Studies of the effects of fishing on benthic habitat and overall ecosystem, utilizing closed areas as experimental controls.
- Studies on trophic dynamics and species interactions among fisheries, marine mammals, seabirds, and forage fish populations.
- Time-series data on economic parameters in the fisheries, including fixed and variable costs associated with fishing and processing, prices, inventories and exports, ownership patterns, employment patterns, and location of expenditures for goods and services.
- Comprehensive research to identify and quantify the linkages between fisheries and the economic and social life in coastal communities.
- Research on gear modification and other methods to reduce bycatch or minimize mortality.
- Ongoing analysis of the accuracy and precision of catch estimates in the fisheries.
- Development of catch and bycatch sampling procedures to support programs of individual accountability for bycatch.
- Research on the linkages between fisheries and Steller sea lion recovery, including evaluation of impacts of no-trawl zones.

Evaluation

The NMFS Alaska Fisheries Science Center, along with other institutions such as the University of Alaska, ADF&G, the Prince William Sound Science Center, and others have all been doing ecosystem level research. This research is expected to continue at about the current level.

4.9.2 Ecosystem Impacts of the Alternatives

Fishing has the potential to influence ecosystems in several ways. Fishing may alter the amount and flow of energy in an ecosystem by removing energy and altering energetic pathways though the return of discards and fish processing offal back into the sea. The recipients, locations, and forms of this returned biomass may differ from those in an unfished system. Selective removal of species and sizes of organisms has the potential to change predator-prey relationships and community structure. Introduction of nonnative species may occur through emptying of ballast water in ships from other regions (Carlton 1996). These species introductions have the potential to cause large changes in community dynamics. Fishing can alter different measures of diversity. Species level diversity, or the number of species, can be altered if fishing essentially removes a species from the system. Fishing can alter functional or trophic diversity if it selectively removes a trophic guild member and changes the evenness with which biomass is distributed among a trophic guild. Certain species, such as pollock, are at a central position in the food web and their abundance is an indicator of prey availability for many species. Fishing can alter genetic level diversity by selectively removing faster growing fish or removing spawning aggregrations that might have different genetic characteristics than other spawning aggregations. Fishing gear may alter bottom habitat and damage benthic organisms and communities (a topic covered in Section 4.7).

Much has been written about possible indicators of ecosystem status in response to perturbations (e.g., Odum 1985, Pauly et al. 1998, Rice and Gislason 1996, Murawski 2000). These indices can show changes in energy cycling and community structure that might occur due to some external stress such as climate or fishing. For example, fisheries might selectively remove older, more predatory individuals. Therefore, one would expect to see changes in the size diversity spectrum (the proportion of animals of various size groups in the system), mean age, or proportion of r-strategists (faster growing, more fecund species such as pollock) in the system. These changes can increase nutrient turnover rates because of the shift toward younger, smaller organisms with higher turnover rates. Total fishing removals and discards also provide a measure of the loss and redirection of energy in the system due to human influences. Total fishing removals relative to total ecosystem energy could indicate the importance of fishing removals as a source of energy removal in an ecosystem. Changes in scavenger populations that show the same direction of change as discards could be an indicator of the degree of influence discards have on the system. Discards as a proportion of total natural detritus would also be a measure that could indicate how large discards are relative to other natural fluxes of dead organic material. Levels of total fishing removal or fishing effort could also indicate the potential for introduction of nonnative species through ballast water in fishing vessels. Fishing practices can selectively remove predators or prey. Tracking the change in trophic level of the catch may provide information about the extent to which this is occurring (e.g., Pauly et al. 1998). Thus, measures of total catch, total discard, and information about the changing mean size of organisms will be used to indicate the potential of each alternative to impact ecosystem energy flow and turnover.

Total catch and trophic level of the catch will also provide information about the potential to disrupt predator-prey relationships through introduction of nonnative species or fishing down the food web through selective removal of predators. Angermeier and Karr (1994) also recognized that an important factor affecting the trophic base is spatial distribution of the food. These factors will be evaluated to determine the potential of each alternative to disrupt predator-prey relationships.

The scientific literature on diversity is somewhat mixed about what changes might be expected due to a stressor. Odum (1985) asserts that species diversity (number of species) would decrease and dominance (the degree to which a particular species dominated in terms of numbers or biomass in the system) would increase if original diversity was high, while the reverse might occur if original diversity was low. Genetic diversity can also be altered by humans through selective fishing (removal of faster growing individuals or certain spawning aggregations). Accidental releases of cultured fish and ocean ranching tends to reduce genetic diversity (Boehlert 1996). More recently, there is growing agreement that functional (trophic) diversity might be the key attribute that lends ecosystem stability (see review by Hanski 1997). This type of diversity ensures there are sufficient number of species that perform the same function so that if one species declines for any reason (human or climate-induced), then other species can maintain that particular ecosystem function and less variability would occur in ecosystem processes. However, measures of diversity are subject to bias and how much change in diversity is acceptable is not really known (Murawski 2000). Furthermore, diversity may not be a sensitive indicator of fishing effects (Livingston et al. 1999, Jennings and Reynolds 2000). Nonetheless, the possible impacts the alternatives may have on various diversity measures will be assessed.

Quantitative measures of some of the indicators mentioned above have been summarized for each of the alternatives. These include total catch, trophic level of the catch, total discards, total groundfish biomass, diversity (Simpson's richness index), trophic level of groundfish biomass, and amount of pollock or other forage for the BSAI and GOA (Table 4.9-2). For each alternative, the possible impacts are addressed for on (1) predator-prey relationships, including introduction of nonnative species; (2) energy flow and redirection (through fishing removals and return of discards to the sea); and (3) diversity, using a system of ranking the changes seen in the indicators for each alternative, with positive ranks given to beneficial directions of change, negative ranks given to directions of change that would provide less protection, and zeros given to neutral changes (Tables 4.9-3 and 4.9-4). The summary tables contain an ordinal index for each of several types of potential effects of each alternative relative to Alternative 1. The index is represented by the values {-2, -1, +0, +1, or +2}. An index value of +0 indicates that there is no expected change relative to Alternative 1. A negative index value indicates that the impact of the alternative is expected to be worse than Alternative 1. A positive index value indicates that the impact of the alternative is expected to be better than Alternative 1. Since the index values only contain ordinal information, they can only be used to make ordinal comparisons. For example, an index value of +2 is better than a value of +1, but it is not true, in general, that a +2 is twice as good or twice as large as a +1. In short, the index values are simply place holders that represent an ordering. A completely equivalent ordering could be represented by a, b, c, d, or e. Therefore, it is not possible to obtain meaningful summary information by performing numerical operations (e.g., add or subtract index values or calculate their ratios) using two or more of the index values.

4.9.2.1 Effects on Predator-Prey Relationships, Including Introduction of Nonindigenous Species

Alternative 1

As noted earlier, fisheries can remove predators, prey, or competitors and thus alter predator-prey relationships relative to an unfished system. Studies from other ecosystems have been conducted to determine whether predators were controlling prey populations and whether fishing down predators produced a corresponding increase in prey. Similarly, the examination of fishing effects on prey populations has been conducted to evaluate impacts on predators. Finally, fishing down of competitors has the potential to produce species replacements in trophic guilds (see reviews of all these effects in Hall 1999b). Evidence from other ecosystems presents mixed results about the possible importance of fishing in causing population changes of the fished species' prey, predators, or competitors. Some studies showed a relationship, while others showed that the changes were more likely due to direct environmental influences on the prey, predator or competitor species rather than a food web effect. Thus, fishing does have the potential to impact food webs but each ecosystem must be examined to determine how important it is for that ecosystem.

Most of the work on predator-prey relationships in the BSAI and GOA regions has been done in the eastern Bering Sea. Evidence from modeling studies and examination of trophic guild changes (see Section 3.9) suggest that under Alternative 1, there is no clear evidence of fishing as the cause of species fluctuations through food web effects. Multispecies models have shown that although cannibalism can explain a large part of the density-dependent part of the stock recruitment relationship for pollock (that is, the decline in recruitment observed at high spawner biomasses), most of the overall variability in stock and recruitment is not explained by predation (Livingston and Methot 1998). Pollock is a key prey species of many target and nontarget species in the Bering Sea and GOA (Livingston 1989a, 1994) and has a central position in the food webs of those ecosystems. Modeling of predation on pollock in the eastern Bering Sea and GOA (Livingston and Methot 1998, Livingston and Jurado-Molina 1999, and Hollowed et al. 2000) shows that different predators may be the most important source of predation mortality during different time periods. For example, Steller sea lion predation on pollock in the GOA was more important in earlier years but the most important current source of predation mortality on pollock is now from arrowtooth flounder. Population levels of some of these predators such as arrowtooth flounder appear unrelated to fishing removals but are more linked to environmental forces that favor the production of these species (Hollowed et al. 1998). Similarly, the fluctuations observed in species composition of trophic guilds (Livingston et al. 1999) do not appear to be related to fishing removals of competitors or prey, when analyzed at the aggregated level for the whole eastern Bering Sea. Measures of pelagic forage abundance in the status quo indicate in the short term that from 2001 to 2005, the fraction of pollock in total groundfish biomass is predicted to increase 6 percent in the BSAI and 29 percent in the GOA. These are substantial increases for pollock abundance, particularly in the GOA, and would be considered a significant positive effect of the status quo on the environment in the short term.

However, the above analyses did not consider space and time removals of prey by fisheries. Concentrated fishing removals of key prey species in space and time has been of concern in the status quo regime and time and area closures have recently been implemented to attempt to remedy the possible effects of these removals on predator species, particularly Steller sea lions. There has not been sufficient observation time to evaluate the effectiveness of these closures in protecting prey availability to predators, though presumably they have a beneficial effect in the short term if predators are prey limited, particularly for predators seeking commercial-sized prey in the closed areas. Until the effectiveness of the present closures is seen, the impact of the present regime in concentrating removals of prey in space and time is considered to have a conditionally significant adverse effect.

Fishing can selectively remove fish eating predators then move down the food web and begin removing the next trophic level down such as plankton feeding fish. This process is known as fishing down the food web. Trophic level of the fish and invertebrate catch from the BSAI, and GOA was estimated from the 1960s to the present (Queirolo et al. 1995, Livingston et al. 1999) to determine whether such fishing down effects were occurring. Trophic level of the catch in all three areas has been relatively high and stable over the last 30 or more years. There is no evidence from the present fishery management regime that this fishing down the food web process has occurred. Trophic level of the catch under Alternative 1 is not expected to change appreciably (Table 4.9-2), with changes of 1 percent or less predicted between 2001 and 2005.

Species composition of the catch indicates that some predatory populations such as arrowtooth flounder have been lightly exploited and the focus over time has been on mixed fish and invertebrate feeders such as pollock and cod. Protection of forage species from directed fisheries was implemented in recent years and this has also reduced the possibility of fishing down the food web under the status quo regime. The biomass of pollock, a key prey species, in the groundfish biomass is predicted to increase in the short-term under Alternative 1, with a 12 percent and 47 percent increase in the BSAI and GOA, respectively over 2001 to 2005. Changes in functional species composition might be indicated by changes in diversity of the groundfish community. No appreciable changes in the trophic level of the groundfish biomass are seen in the Alternative 1 from 2001 to 2005 (Table 4.9-2). Thus, with regard to removal of top predators, the present regime is considered to have an insignificant effect on the environment.

Fishing vessels and vessels supporting fishing operations have the potential to disrupt predator-prey relationships through the introduction of nonindigenous species. These introductions occur when ship ballast water containing live organisms is obtained outside a region and is released into fishery management areas. Vessels also have organisms fouling their hulls that can be transported between regions. These organisms have the potential to cause large alterations in species composition and dominance in ecosystems (Carlton 1996). Recent work done primarily in Port Valdez and Prince William Sound shows that biological introductions of nonindigenous species has occurred, although these introductions cannot be ascribed to a particular vessel type, such as oil tankers or fishing vessels (Hines and Ruiz 2000). There have been 24 species of nonindigenous species of plants and animals documented primarily in shallow water marine and estuarine ecosystems of Alaska, with 15 species recorded in Prince William Sound. One example of a likely introduction is the predatory seastar *Asterias amurensis*, which is found in other areas of Alaska but has not previously been found in Cook Inlet. These predators have the potential to have a major impact on benthic communities. Impacts from these introductions have not yet been observed in Alaskan waters, but because they could potentially produce large-scale changes in predator-prey interactions and species composition they are judged to have a conditionally significant effect on the environment.

Table 4.9-2 Indicators of Amounts of Energy Removal and Redirection and Trophic Position of Removals for the Eastern Bering Sea and Aleutian Islands and the Gulf of Alaska for the Alternative 1 and Percent Change Between Other Alternatives for 2005

Indicator	Alternative 1			Percent change from Alternative 1 in 2005							
	2001	2005	Percent change	2.1	2.2	3	4.1	4.2	5	6.1	6.2
BSAI Total catch biomass (mt)[a]	1,743,728	1,739,018	<1	-20	-80	-10	-10	-14	<1	1	16
Trophic level catch	3.73	3.73	<1	<1	-1	<1	<1	<1	<1	<1	<1
Discards (mt)[b]	159,708	117,069	-28	-15	-57	3	3	-6	-3	40	26
Total groundfish biomass (mt)[c]	17,696,828	18,736,597	6	7	22	3	4	5	<1	<1	-4
Simpson's richness index[d]	3.6	3.3	-8	-4	-13	-3	-5	-4	1	<1	1
Total pollock biomass (mt)	8,493,650	9,532,480	12	10	34	6	7	7	<1	<1	-5
Trophic level total groundfish biomass	3.68	3.68	<1	<1	<1	<1	<1	<1	<1	<1	<1
GOA Total catch biomass(mt)[a]	228,048	286,154	25	-33	-54	-14	<1	<1	<1	1	24
Trophic level catch	4.01	3.97	-1	<1	-2	<1	<1	<1	<1	<1	1
Discards (mt)[b]	46,123	47,338	3	-7	-16	-2	1	-1	-4	-3	36
Total groundfish biomass (mt)[c]	3,326,535	3,811,909	15	7	9	3	<1	<1	1	<1	-4
Simpson's richness index[d]	3.0	3.1	3	2	3	1	<1	<1	<1	<1	-1
Total pollock biomass (mt)	777,449	1,146,170	47	14	17	6	<1	<1	<1	<1	-7
Trophic level total groundfish biomass	4.17	4.15	<1	<1	<1	<1	<1	<1	<1	<1	<1

Notes: [a]Total catch biomass (in metric tons) includes target and non-target species, including prohibited species. Prohibited species catches that are typically reported in numbers were converted into weight using 1999 observer data on total weight and numbers of each prohibited species category to derive a mean individual weight which was then applied to estimated catch from the catch projection model.
[b]Discards include managed species discards, prohibited species, and other species. Alternative 1 assumes discards of yellowfin sole and rock sole in the BSAI and shallowwater flatfish in the GOA would not occur beginning in 2003, when the improved retention requirements for those species would begin.
[c]Includes only species that are analyzed using single species age-structured models.
[d]This index is estimated from the biomasses of the groundfish species that are analyzed using age structured models using the following formula:
[e]$1/\sum p^2$ where p = proportion of each groundfish species biomass relative to total groundfish biomass.
BSAI – Bering Sea and Aleutian Islands GOA – Gulf of Alaska mt – metric tons

Table 4.9-3 Scoring System for Effects of the Alternatives on Predator-Prey Relationships, Energy Flow and Balance and Diversity

Issue	Effects		Score				
			-2	-1	+0	+1	+2
Predator-prey relationships	1.	Pelagic forage availability	Large decrease in total pollock or other key forage abundance (greater than10 percent)	Decrease in total pollock or other key forage abundance (5 to 10 percent)	No change in total pollock or other key forage abundance (less than 5 percent change)	Increase in total pollock or other key forage abundance (5 to 10 percent)	Large increase in total pollock or other key forage abundance (greater than 10 percent)
	2.	Spatial and temporal concentration of fishery impact on forage	Greater temporal and spatial compression	Greater temporal or spatial compression	Same temporal and spatial fishery distributions on key forage (pollock, Atka mackerel)	Less temporal or spatial compression	Less temporal and spatial compression
	3.	Removal of top predators		Trophic level of catch relative to trophic level of biomass is higher	No change in trophic level of catch relative to trophic level of biomass	Trophic level of catch relative to trophic level of biomass is lower	
	4.	Introduction of nonnative species	Much higher total catch (greater than 10 percent)	Higher total catch (5 to 10 percent)	No change in total catch	Lower total catch (5 to 10 percent)	Much lower total catch (greater than10 percen)
Energy flow and balance	1.	Energy re-direction (discards)	Much higher discards (greater than10 percent)	Higher discards (5 to 10 percent)	No change in discards	Lower discards (5 to 10 percent)	Much lower discards (greater than10 percent)
	2.	Energy removal (catch)	Large increase in total catch (greater than10 percent)	Increase in total catch (5 to 10 percent)	No change in catch removals	Decrease in total catch (5 to 10 percent)	Large decrease in total catch (greater than 10 percent decrease)

Table 4.9-3 (Cont.) Scoring System for Effects of the Alternatives on Predator-Prey Relationships, Energy Flow and Balance and Diversity

Issue	Effects		Score			
		-2	-1	+0	+1	+2
Diversity	1. Species diversity	Less stringent policies for the protection of many ecosystem components	Less stringent policies for protection of a few ecosystem components	status quo policies that protect ecosystem components	More stringent policies for protection of a few ecosystem components	More stringent policies for protection of many ecosystem components
	2. Functional (trophic) diversity		Increased levels of fishing-induced changes in functional diversity	Same levels of fishing-induced changes in functional diversity	Reduced levels of fishing-induced changes in functional diversity	
	3. Genetic diversity		Increased fishing on spawning aggregations or larger fish	Same levels of fishing on spawning aggregations and larger fish	Decreased fishing on spawning aggregations or larger fish	

Table 4.9-4 Assessment of the Impact of the Alternative 1 on the Environment and Summary of Scores for Each Alternative, Reflecting Relative Levels of Protection for Predator-prey Relationships, Energy Flow and Balance, and Diversity

Species, Species Groups, and Effects	Alternatives[b]								
	1[a]	2		3	4.1	4.2	5	6.1	6.2
		2.1	2.2						
Predator-prey relationships									
Pelagic forage availability	S(+)	1	2	1	1	1	1	0	-1
Spatial and temporal concentration of fishery on forage	CS(-)	2	2	-1	1	1	1	2	-2
Removal of top predators	NS	0	0	0	1	1	0	0	0
Introduction of nonnative species	CS(-)	2	2	2	1	2	1	0	-2
Energy flow and balance									
Energy redirection (discards)	NS	2	2	0	0	1	1	-2	-2
Energy removal (catch)	NS	2	2	2	2	2	0	0	-2
Diversity									
Species diversity	CS(-)	1	1	2	2	2	2	0	-2
Functional (trophic) diversity	NS	0	0	0	1	1	1	0	0
Genetic diversity	NS	1	1	1	1	1	0	0	-1

Notes: [a]Scoring of status quo impacts: Not Significant – Nonsignificant impact; S (+ or -) = Significant beneficial or adverse impact; CS (+ or -) = Conditionally significant beneficial or adverse impact (some information suggests that significant effects could occur, but the intensity of effect and probability of occurrence are unknown).

[b]The index values contain ordinal information and can only be used to make ordinal comparisons. For example, an index value of 2 is better than a value of 1, but a 2 is not necessarily twice as good or twice as large as 1. Therefore, it is not possible to obtain meaningful summary information by performing numerical operations (e.g., add or subtract index values or calculate their ratios) using two or more index values.

Alternative 2.1

Alternative 2.1 has the potential to make fishery-sized cod, pollock, and Atka mackerel more available to predators in time and space through a combination of TAC reduction and spreading the prey removal over time and space. Thus, in the short-term, Alternative 2.1 would tend to better protect the trophic base of predators, particularly marine mammals, that rely on these prey relative to Alternative 1. Benefits to these predators would result if they encounter some prey limitation in the present regime. In the short term, non-mammal predators that might benefit through increased adult pollock and Atka mackerel include Pacific cod, Pacific halibut, sablefish, and Greenland turbot. Indirect impacts of Alternative 2.1 could occur by reducing the prey base of other species that compete for food with the Pacific cod, pollock, and Atka mackerel that are not taken. However, there are no indications that food is limiting to these other groundfish species so this indirect effect is likely to be minimal. No large changes are expected in species composition in the ecosystem due to Alternative 2.1 because variability in the main species affected (pollock) appears to be more driven by recruitment variability than changes in TAC.

In the long-term, multispecies age-structured predator-prey modeling indicates that when there is decreased fishing on pollock, predators of the smallest sizes of pollock, such as adult pollock and northern fur seal, tend to get more prey (Jurado-Molina and Livingston 2000), but predators of adult pollock may not see this benefit. Increased predation on rock sole, yellowfin sole, and Pacific herring would be predicted by this multispecies forecasting model if Pacific cod were fished at lower rates. Also, when no-fishing scenarios are tested in this multispecies model, the model predicts much lower stock biomasses in the long term than what single-species models predict, particularly for species that are prey in the modeled system, such as pollock, rock sole, and yellowfin sole. Thus, the single-species predictions of increases in pollock biomass when fishing is lowered under Alternative 2.1 might not be as large in the long term if multispecies considerations are taken into account.

Aggregated (non-age structured) ecosystem model simulations for the Bering Sea, using the ECOSIM model, predict long-term decreases in juvenile pollock and populations of piscivorous birds, which rely on juvenile pollock as prey, but no changes in marine mammal populations when there is no fishing on pollock (Trites et al. 1999). As mentioned in Section 3.9, when the newer version of the ECOMSIM model is run, which has a different way of considering pollock recruitment, an increase in juvenile pollock and piscivorous birds is seen but there is still no change in marine mammal populations (Kerim Aydin, University of Washington School of fisheries and Aquatic Sciences personal communication). Assumptions about recruitment influence the results of these models, and these assumptions can change the direction of the predicted changes, particularly for pollock. These models also lack spatial definition, which is most critical in evaluation of this alternative. Given the importance of availability of prey in space and time, spatial foraging models need to be developed to better understand the possible impacts of Alternative 2.1 on predators of adult pollock, such as marine mammals.

Alternative 2.1 would increase key forage species biomass at least in the short term. Although the alternative is intended to benefit marine mammals, two key prey species considered (pollock and Atka mackerel) are central prey species in either the pelagic food webs of the BSAI or the GOA. Thus, Alternative 2.1 ranks +1 in influencing the ecosystem issue of pelagic forage availability (Table 4.9-4).

The explicit consideration of spreading out fishery removals of these key prey species in space and time under this Alternative 2.1 gives it a rank of +2 for potential benefits to the ecosystem for decreasing the spatial and temporal concentration of fisheries on forage species.

Trophic level of the catch shows little change from Alternative 1 (Table 4.9-2). No additional tendency to fish down the food web occurs under Alternative 2.1. As an indicator of forage availability, some additional increases over Alternative 1 are seen in the proportion of pollock in the groundfish biomass when single-species models are used to evaluate changes in groundfish biomass, 3 percent and 7 percent increases over the Alternative 1 2005 for the Bering Sea and GOA, respectively. Trophic level of the total groundfish biomass (Table 4.9-2) would not change relative to Alternative 1, indicating little change in the functional species composition of the groundfish community. Thus, trophic level of the catch relative to trophic level of groundfish biomass is about the same, giving Alternative 2.1 a neutral rank with respect to influencing the ecosystem effect of removal of top predators.

Presumably, the seasonal TAC reductions of Alternative 2.1 would translate into fewer fishing vessels or fishing effort for these species. Thus, there are lower probabilities for the introduction of nonindigenous species under Alternative 2.1 relative to Alternative 1. The total catch reductions of greater than 10 percent would indicate less fishing effort, which would be related to the possibility for introduction of nonindigenous species. Thus this alternative ranks a +2 for potential reduction in possibility of introduction of nonnative species.

Alternative 2.2

Alternative 2.2 has the potential to make fishery-sized pollock, cod, and Atka mackerel more available to predators in time and space by using large TAC reductions. Thus, Alternative 2.2 would tend to better protect the trophic base of predators, particularly marine mammals, that rely on these prey relative to Alternative 1. Benefits to these predators would result if they are encountering some prey limitation in the present regime. In the short term, non-mammal predators that might benefit through increased adult pollock and Atka mackerel include cod, Pacific halibut, sablefish, and Greenland turbot. Indirect impacts of Alternative 2.2 could occur by reducing the prey base of other species that compete for food with the cod, pollock, and Atka mackerel that are not taken. However, there are no indications that food is limiting to these other groundfish species so this indirect effect would likely be minimal. Large changes in species composition in the ecosystem would not be expected under Alternative 2.2 because variability in the main species affected (pollock) appears to be more driven by recruitment variability than changes in TAC.

In the long term, multispecies age-structured predator-prey modeling indicates that when there is decreased fishing on pollock, predators of the smallest sizes of pollock, such as adult pollock and northern fur seal, tend to get more prey (Jurado-Molina and Livingston 2000), but predators of adult pollock may not see this benefit. Increased predation on rock sole, yellowfin sole, and Pacific herring would be expected if Pacific cod were fished at lower rates. Also, when no-fishing scenarios are tested in this multispecies model, much lower stock biomasses are predicted for the long term than by single-species models, particularly for species that are prey in the modeled system, such as pollock, rock sole, and yellowfin sole. Thus, the single-species predictions of increases in pollock biomass when fishing is lowered under Alternative 2.2 might not be as large in the long-term if multispecies considerations are taken into account.

Aggregated (non-age structured) ecosystem model simulations for the Bering Sea using ECOSIM predict long-term decreases in populations of piscivorous birds and and juvenile pollock but no changes in marine mammal populations when there is no fishing on pollock (Trites, et al. 1999). Adult pollock populations would increase only about 5 percent in the long term if fishing were stopped. As mentioned in Section 3.9, running the newer version of this model, which has a different way of considering pollock recruitment, results in an increase in juvenile pollock and piscivorous birds but still no change in marine mammal populations (Kerim Aydin, personal communication). Assumptions about recruitment influence the results of these models, and these assumptions can alter the direction of the predicted changes, particularly for pollock. These models also lack spatial definition, which is critical in evaluating Alternative 2.2. Given the importance of availability of prey in space and time, spatial foraging models need to be developed to better understand the possible impacts of this alternative on predators of adult pollock, such as marine mammals.

Alternative 2.2 would increase key forage species biomass, at least in the short term. Although Alternative 2.2 objectives were intended to benefit marine mammals, two key prey species considered (pollock and Atka mackerel) are central prey species in either the pelagic food webs of the BSAI or the GOA. Thus, Alternative 2.2 ranks +2 in influencing the ecosystem issue of pelagic forage availability (Table 4.9-4).

Although Alternative 2.2 would not explicitly reducet fishery catch in space, the TAC levels proposed and the timing of catches indicate that there would likely be a reduction of both spatial and temporal catches of key ecosystem forage species, Atka mackerel and pollock. Thus, Alternative 2.2 ranks +2 in terms of providing increased protection against temporal and spatial concentrations of fisheries on forage.

Trophic level of the catch would decline by less than 2 percent relative to Alternative 1 for the BSAI. Alternative 2.2 does not show any increased tendency to fish down the food web relative to the Alternative 1. Trophic level declines would be purely due to change in fishery targets, not a sequential fishing down effect. As an indicator of forage availability, some additional increases over the Alternative 1 would be seen in the proportion of pollock in the groundfish biomass when single species models are used to evaluate changes in groundfish biomass, 10 percent and 3 percent increases over Alternative 1 in 2005 for the Bering Sea and GOA, respectively. Trophic level of the total groundfish biomass (Table 4.9-2) would not change relative to Alternative 1, indicating little change in the functional species composition of the groundfish community. Thus, Alternative 2.2 would be neutral (e.g., +0) with respect to providing additional protection to fishing down the food web through removal of top predators.

The large TAC reductions under Alternative 2.2 would translate into fewer fishing vessels or less fishing effort for these species. Thus, there would be fewer possibilities for the introduction of nonindigenous species through groundfish fishing vessels under Alternative 2.2 relative to Alternative 1, and scores +2.

Alternative 3

Alternative 3 has the potential to protect predator-prey interactions by protecting stock levels through minimum stock size thresholds (MSST) and incorporating uncertainty (which would lower TACs of some species). No large changes in species composition in the ecosystem would be expected due to this alternative because variability in the groundfish species affected appears to be more driven by recruitment variability than changes in TAC. Pelagic forage availability, as measured by the fraction of pollock in the groundfish biomass would increase slightly, but not more than 5 percent above Alternative 1. However, Alternative 3 would make large reductions (almost 40 percent) in the TACs of Atka mackerel, thus is given a score of +1. Although 20 percent time and area closures would provide a consistent fraction of undisturbed area in each management zone for predators to find prey, the TAC displacement into other areas has the potential to increase local prey depletion in those areas, giving Alternative 3 a -1 with respect to spatial and temporal concentrations of fisheries on the key forage species Atka mackerel and pollock.

In the short term, the shift in fishery selectivity toward older fish might tend to remove more older, predatory individuals relative to Alternative 1, which could potentially reduce any possible competition for prey with other predators. However, because of the decline in fishing mortality due to the uncertainty corrections, the long-term equilibrium age composition of these populations might actually show an increase in older more predatory individuals relative to Alternative 1. More research needs to be done that looks at the changes in ecosystem-level size frequency distributions that might be expected if the size frequencies of groundfish removals are altered.

Trophic level of the catch would not decline under Alternative 3 relative to Alternative 1. However, the trophic levels of each species were not explicitly modeled by size. Potentially, Alternative 3 could show an increase in trophic level of the catch if this feature of increasing predatory behavior with increasing size of fish were modeled. Alternative 3 could show a slight reduction in the fishing down effect through the increase in the lifespan of target fish induced by the decreased fishing mortalities in the long term. Although Alternative 3 has the potential to show an increase in trophic level of the catch relative to Alternative 1, it is likely not a very large change. Similarly, trophic level of the total groundfish biomass does not show any change relative to Alternative 1, although there is some potential for increased trophic level if trophic level changes with respect to changing size distributions were modeled. Thus, Alternative 3 would not differ from Alternative 1 with respect to its potential for fishing down large predators (e.g., +0).

Total catch reductions under Alternative 3 would likely mean smaller fishing effort or fewer fishing vessels in the region. Thus, there would be lower probabilities for the introduction of nonindigenous species under Alternative 3 relative to Alternative 1, therefore Alternative 3 scores a +2.

Alternatives 4.1 and 4.2

Alternatives 4.1 and 4.2 could alter predator-prey relationships primarily by the closure of areas to protect squid aggregations and the resulting TAC reduction of pollock. Squid is a prey species of marine mammals and some slope-dwelling groundfish. Closed areas to protect squid would provide more squid as prey to these animals relative to Alternative 1, and would provide some benefits to predators over Alternative 1 if these prey are presently limiting. There is presently no evidence that prey are limiting to slope dwelling groundfish. TAC reduction of pollock would also tend to provide more fishery-sized pollock to animals such as some marine mammals, cod, Greenland turbot, and sablefish, which consume these larger sized pollock. Benefits to these predators would occur if pollock prey are a limiting factor to these groups. There is presently no evidence that pollock is limiting groundfish species. Eastern Bering Sea pollock biomass would increase about 7 percent relative to Altertnative 1 under Alternatives 4.1 and 4.2, so they give increased protection relative to Alternative 1 with respect to providing greater availability of pelagic forage as measured by pollock abundance. Also, these are the only alternatives that explicitly attempt to provide additional protection to another important pelagic forage species, squid. Although there is no explicit measure of the potential increase in squid abundance, Alternatives 4.1 and 4.2 would provide increased availability of this pelagic forage so they receive a +1 score with respect to this measure.

The closed area to protect squid would also provide some reduction in spatial concentration of pollock fishing so there is some additional protection to spatial and temporal concentration of fisheries on forage relative to Alternative 1. Alternatives 4.1 and 4.2 were both given a +1 score for this metric.

No change in trophic level of the catch would be seen under Alternatives 4.1 and 4.2 relative to trophic level of the total groundfish biomass. Thus, they appear to provide no further protection to fishing down the food web relative to Alternative 1. However, if Alternatives 4.1 and 4.2 were implemented to species beyond the example species of skates, squids, and grenadiers, they would provide increased protection to fishing down top predators such as sharks, and thus they receive a +1 relative to Alternative 1 on this issue.

Some decreases in the amount of fishing vessels or effort might occur due to the TAC reduction of pollock. Thus, Alternatives 4.1 and 4.2 might provide some additional increase in protection from the introduction of nonindigenous species relative to Alternative 1. Alternative 4.1 was given a score of +1 and Alternative 4.2, which would have more catch reduction than Alternative 4.1, scores +2 on this metric relative to Alternative 1.

Alternative 5

Alternative 5 could change predator-prey relationships relative to Alternative 1 by providing some areas that would be totally closed to fishing (HAPC areas) and reducing the TAC of flatfish and Atka mackerel, which could provide additional prey to species that consume them. Some reductions in the abundance of older, more predatory fish might occur by changing the fisheries for Greenland turbot, some rockfish, sablefish, and cod to fixed-gear only, which has greater selectivity for older fish. The HAPC area closures would provide areas where prey populations were not disturbed and could be more beneficial to predators relative to Alternative 1. TAC reductions of flatfish and Atka mackerel could potentially benefit Pacific cod, Pacific halibut, arrowtooth flounder, and Greenland turbot by providing additional prey for them in short term. However, in the long term, multispecies modeling indicates that if there are species that consume younger ages of these species relative to these predators, then the species that consume the smallest sizes tend to benefit the most. Pollock biomass increases slightly relative to Alternative 1 but Alternative 5 would reduce TAC of Atka mackerel by 8 percent in the Aleutian Islands, and thus it deserves a +1 score for providing increased pelagic forage availability relative to Alternative 1.

Reducing the disturbance of benthic prey through bottom trawling would provide a less disturbed prey base for benthic feeding animals. Scavenging animals that presently benefit to some degree by trawls that expose benthic prey to predation would experience a decline in this benefit under Alternative 5 relative to Alternative 1. The actual magnitude of the positive benefits to non-scavenging predators is not known, but would be greater under this alternative compared to Alternative 1. Changing the selectivity toward gear that removes older fish would reduce energy flow at higher trophic levels, which would shorten the food chain and decrease the lifespan of organisms (both of which would occur to some extent through the change in fishery selectivity toward older fish). These would be indicators of a more stressed, less mature ecosystem according to Odum (1985). No quantitative measures are available of the extent to which these processes would be affected. However, the magnitude of the change proposed in removal of higher level predators relative to changes observed due to environmentally driven changes in recruitment suggest that there would not likely be a large ecosystem impact in this regard from Alternative 5.

Alternative 5 would close additional areas to fishing and reduce TAC outside these areas for flatfish and Atka mackerel. It thus would provide additional protection to spatial compression of fisheries on forage species relative to the Alternative 1, and receives a score of +1.

There would be little change in trophic level of the catch relative to trophic level of the groundfish biomass under Alternative 5. Thus it would provide similar protection as Alternative 1 to fishing down effects on top predators in the food web (+0).

TAC reductions of flatfish and Atka mackerel could presumably decrease the number of vessels or amount of effort in the management areas. Thus, this alternative might provide some additional increase (e.g., +1) in protection from the introduction of nonindigenous species relative to Alternative 1.

Alternative 6.1

The main predator-prey-related effects of Alternative 5 would be to spread out the removal of either predators or prey over space and time due to the elimination of the race for fish. Fishing practices, such as the use of larger mesh sizes, might also be used to decrease the catch of less desirable sizes of fish and thus would tend to increase the removal of larger, more predatory fish from the system. Pelagic forage availability as measured by pollock biomass would not change relative to Alternative 1, giving this alternative a +0 score in this respect.

Alternative 5 would reduce the race for fish and spread fisheries over time. Because of this extra time to catch fish, fishermen would also increase their exploratory fishing and would spread out fishing in space. Thus Alternative 5 would reduce spatial and temporal concentrations of fisheries on forage relative to Alternative 1, giving Alternative 5 a rank of +2.

Presumably, species that rely heavily on adult groundfish for prey in space and time would have less population variability so more stability would be likely in ecosystem biomass. The shift in fishery selectivity toward older fish would tend to remove more older, predatory individuals relative to Alternative 1, potentially reducing any possible competition for prey with other predators. Large changes in species composition would not be expected in the ecosystem due to Alternative 5, because variability in affected groundfish species appear to be more driven by recruitment variability. Reduced energy flow at higher trophic levels, which would shorten the food chain and decrease the lifespan of organisms (both of which would occur to some extent through the change in fishery selectivity toward older fish), would be indicators of a more stressed, less mature ecosystem according to Odum (1985). No quantitative measures are available of the extent to which these processes would be affected. However, the magnitude of the change relative to changes observed due to environmentally driven recruitment changes suggest that there would not likely be a large ecosystem impact in this regard from Alternative 5.

There would be little change in trophic level of the catch under Alternative 5 relative to trophic level of biomass. Thus it provides similar protection as Alternative 1 to fishing down effects on the food web (e.g., +0).

Alternative 5 might reduce the number of vessels participating in groundfish fisheries, but could also increase the effort (spread it over space and time). Thus, Alternative 5 might provide no additional increase in protection from the introduction of nonindigenous species relative to Alternative 1.

Alternative 6.2

The main predator-prey-related effects of Alternative 6.2 would be to increase short-term harvests of some economically desirable species such as pollock (a key prey) and cod (an important predator). Pollock biomass would decrease 5 percent and 7 percent in the BSAI and GOA, respectively, relative Alternative 1. Thus, Alternative 6.1 would provide less protection to pelagic forage availability and is given a -1 score.

Increased catches of pollock could also result insignificant increases in spatial or temporal concentrations of prey removals relative to Alternative 1. Therefore this metric was given a score of -2.

There would be little change in trophic level of the catch under Alternative 6.2 relative to trophic level of biomass. Thus it would provide similar protection as Alternative 1 to fishing down effects on the food web (e.g., +0).

Given the large catch increases predicted for Alternative 6.1, there might be an increase in the effort or number of vessels participating in groundfish fisheries. Thus, there would be a much larger potential for introduction of nonnative species through groundfish fishing vessels (e.g., -2).

4.9.2.2 Effects on Energy Flow and Balance, Including Fish Removals and Fish Processing Waste

Alternative 1

Fishing may alter the amount and flow of energy in an ecosystem by removing energy and altering energetic pathways through the return of discards and fish processing offal back into the sea. The recipients, locations, and forms of this returned biomass may differ from those in an unfished system. A mass-balance model of the eastern Bering Sea (Trites et al. 1999) provides some information on fishing removals relative to total system production and the distribution of biomass and energy flow throughout the system in recent times. The trophic pyramids (distribution of biomass at various trophic levels) indicate that biomass and energy flow are distributed fairly well throughout the system (Trites et al. 1999, p. 28 of). These show that the Bering Sea is a more mature system compared to other shelf systems. A more mature system is one that is less disturbed (Odum 1985). Total catch biomass (including non-groundfish removals) as a percentage of total system biomass (excluding dead organic material, known as detritus) was estimated to be 1 percent, a small proportion of total system biomass. Fishery removal rates are based in the most basic sense on the amount of surplus production (the excess of reproduction and growth over natural mortality) (Hilborn and Walters 1992) for fish stocks. Because there is great variability among stocks with regard to the amount of this excess production, it is likely more important that removals stay within the bounds of each individual stock's excess production (a topic that is considered in the individual stock impacts sections). From an ecosystem point of view, total fishing removals are a small proportion of the total system energy budget and are small relative to internal sources of interannual variability in production. Thus, they have an insignificant effect on the environment.

Fisheries can redirect energy in the system by discarding and returning fish processing wastes to the system. These practices take energy and potentially provide them to different parts of the ecosystem relative to the natural state. For example, discards of dead flatfish or small benthic invertebrates might be consumed at the surface by scavenging birds, which would normally not have access to those energy sources. An analysis of the importance of these fisheries practices on the BSAI and GOA ecosystems was conducted by Queirolo et al. (1995), before the improved retention requirements for pollock and cod were mandated. Total offal and discard production at that time was estimated at only 1 percent of the unused detritus already going to the bottom. No scavenger population increases were noted that related to changes in discard or offal production amounts. The annual consumptive capacity of scavenging birds, groundfish, and crab in the eastern Bering Sea was determined to be over ten times larger than the total amount of offal and discards in the BSAI and GOA. Finally, it appeared that the main scavengers of fish processing offal, which primarily consisted of pollock, were also natural pollock predators. Thus, energy flow paths did not seem to be redirected in a large way and have an insignificant impact on the environment.

Discard rates dropped even further after the implementation of retention requirements for all pollock and cod in groundfish fisheries. Managed groundfish species discards dropped below 10 percent of the total catch (down from about 15 percent in the eastern Bering Sea and Aleutian Islands and 20 percent in the GOA, respectively) in 1998. The mandated retention of managed flatfish species (yellowfin sole and rock sole in the BSAI and shallow water flatfish in the GOA) in 2003, which make up the bulk of the remaining discards of managed species, may cause the total discard amounts to decrease 28 percent in the BSAI under Alternative 1 from the year 2001 to 2005 (Table 4.9-2, Figure 4.9-4). Total discards in the GOA are estimated to increase 3 percent under Alternative 1 from 2001 to 2005 because shallow water flatfish are not a dominant source of discards in the GOA (arrowtooth flounder, grenadiers, pollock, and cod are the dominant species in the discards) (Figure 4.9-2). Alternative 1 has removed the largest potential source of energy redirection through discards with the improved retention requirements in the eastern Bering Sea. Discards are estimated to decline to 7 percent of the total catch in the BSAI but would remain constant at about 17 percent of the total catch in the GOA, a reflection of the discard level observed in1999. Combined evidence regarding the level of discards relative to natural sources of detritus and no evidence of changes in scavenger populations that are related to discard trends suggest that Alternative 1 would have insignificant ecosystem impacts through energy removal and redirection.

Discards and offal production can cause local enrichment and change in species composition if discards or offal returns are concentrated. Some evidence of those effects have previously been cited (Thomas 1994) in areas with inadequate tidal flushing (Orcas Inlet in Prince William Sound and in Dutch Harbor) but not in the deep water disposal site in Chiniak Bay off Kodiak Island (Stevens and Haaga 1994). Local ocean properties (water flow and depth) and amount of water discharged per year could be important factors determining the effect of nearshore disposal on local marine habitat and communities. Changes to the processing plant at Dutch Harbor dramatically reduced the amount of offal and ground discards discharged. Improved retention could be causing some increases in the amount of local enrichment due to disposal of increased offal from shoreside processing of newly retained fish. However, increase in offal production for the Bering Sea, if all pollock, cod, rock sole and yellowfin sole were to be retained, would amount to an increase of about 6 percent (NMFS 1996e) and would not likely cause a change in water quality.

Alternative 2.1

The main impact of Alternative 2.1 with regard to amount and flow of energy flow in the ecosystem would be to reduce total level of catch biomass removals from groundfish fisheries by about 33 percent in the GOA and 20 percent in the BSAI from Alternative 1. This retained energy would consist primarily of catch reductions in pollock, Atka mackerel, and cod. This would provide further ecosystem protection for energy flows that involve these species. Catch was determined to be a small proportion of total ecosystem energy under Alternative 1 and Alternative 2.1 would ensure that it is even smaller, thus providing further protection to natural ecosystem energy flow paths and amounts. For this reason, Alternative 2.1 was given a score of +2 relative to Alternative 1.

Discards would be reduced 15 percent in the BSAI and 7 percent in the GOA under Alternative 2.1 relative to Alternative 1, primarily through reductions in the discards of pollock and Atka mackerel (Table 4.9-2). Although negative impacts of the present discarding practices have not been demonstrated, this alternative would provide further restoration of natural energy flow paths over those in Alternative 1, and was given a score of +2.

Alternative 2.2

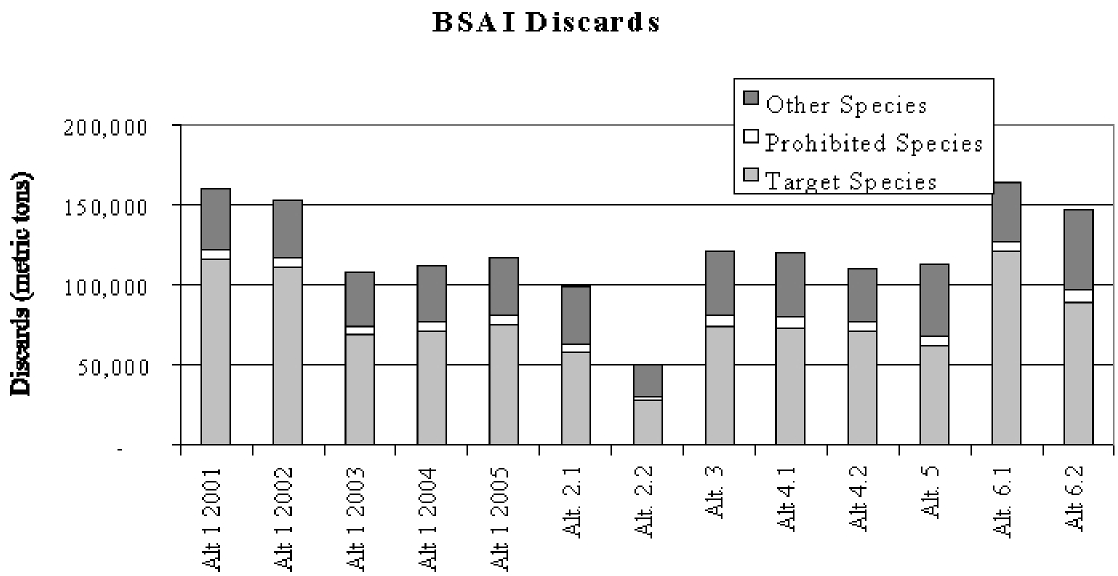
The main impact of Alternative 2.2 with regard to amount and flow of energy flow in the ecosystem would be to reduce total level of catch biomass removals from groundfish fisheries by about 54 percent in the GOA and 80 percent in the BSAI from Alternative 1. This retained energy would consist primarily of catch reductions in pollock, Atka mackerel, and cod. This would provide further ecosystem protection for energy flows that involve these species. Catch was determined to be a small proportion of total ecosystem energy in Alternative 1 and Alternative 2.2 would ensure that it is even smaller, thus providing further protection to natural ecosystem energy flow paths and amounts. For this reason, Alternative 2.2 was given a score of +2 relative to Alternative 1.

Discards would decrease 57 percent in the BSAI and 16 percent in the GOA relative to Alternative 1 (Table 4.9-2). Although negative impacts of the present discarding practices have not been demonstrated, Alternative 2.2 would provide further restoration of natural energy flow paths over those in Alternative 1, and was given a score of +2.

Alternative 3

The main impact of Alternative 3 with regard to energy flow in the ecosystem would be to reduce total level of catch biomass removals from groundfish fisheries by about 14 percent in the GOA and 10 percent in the BSAI from the Alternative 1. Catch was determined to be a small proportion of total ecosystem energy in Alternative 1, and Alternative 3 would ensure that it is even smaller, thus providing further protection to natural ecosystem energy flow paths and amounts. Thus, Alternative 3 scores +2 with respect to its degree of protection of ecosystem energy flow and balance.

Discards under Alternative 3 would increase by 3 percent in the BSAI and decrease by 2 percent in the GOA relative to the status quo alternative level in 2005. Previous analysis of higher discard levels seen before implementation of improved retention requirements for pollock and cod indicated minimal ecosystem impacts at levels higher than those estimated under this alternative (Queirolo et al. 1995). The small increases in estimated discards under this alternative relative to status quo will likely not have negative impacts in the form of increased scavenger populations or anaerobic bottom conditions. Therefore, it received a neutral (e.g., +0) score with respect to energy redirection relative to Alternative 1.



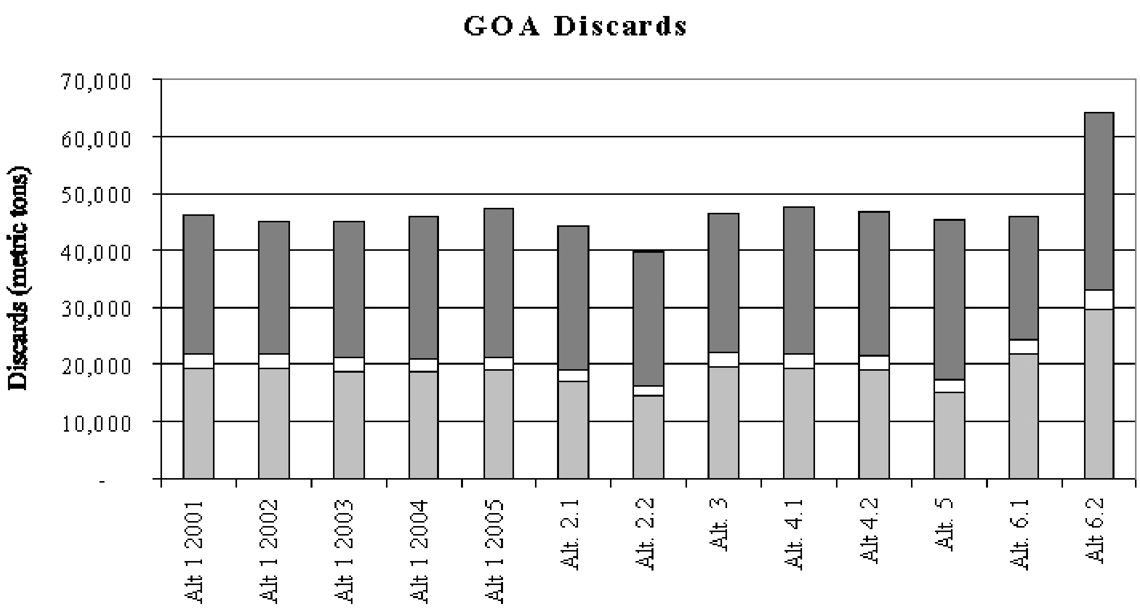


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Figure 4.9-4 Estimated levels of total discards (target species, prohibited species, and non-target species) under Alternative 1 2001–2005 and under Alternatives 2.1 through 6.2 in 2005. The estimates assume that improved retention requirements for yellowfin sole and rock sole in the Bering Sea and shallow water flatfish in the Gulf of Alaska would begin in 2003 and would cause zero discards for those species, beginning in 2003, over all alternatives except 6.1, which removes improved retention requirements.

Alternatives 4.1 and 4.2

The main impact of Alternatives 4.1 and 4.2 with regard to energy flow in the ecosystem would be to reduce total level of catch biomass removals from groundfish fisheries by less than 1 percent in the GOA and 10 percent and 14 percent in the BSAI, respectively from Alternative 1. Catch would be a small proportion of total ecosystem energy under Alternative 1 and Alternatives 4.1 and 4.2 would ensure that it is even smaller, thus providing further protection to natural ecosystem energy flow paths and amounts. For these reasons, Alternatives 4.1 and 4.2 both received a score of +2 relative to Alternative 1.

Discards under Alternatives 4.1 and 4.2 would increase by 3 percent in the BSAI and 1 percent in the GOA in 2005 relative to Alternative 1. Analysis of higher discard levels before implementation of improved retention requirements for pollock and cod indicate that minimal ecosystem impacts would occur at levels higher than those estimated under Alternatives 4.1 and 4.2 (Queirolo et al. 1995). The small increases in estimated discards under Alternatives 4.1 and 4.2 relative to Alternative 1 would likely not have negative impacts in the form of increased scavenger populations or anaerobic bottom conditions. Alternatives 4.1 and 4.2 receive a neutral score of +0 relative to Alternative 1 with respect to providing decreases in the amount of discards.

Alternative 5

Alternative 5 would not change total observed catch amounts appreciably from Alternative 1, and thus would not provide any further protection to natural ecosystem energy flow paths and amounts relative to Alternative 1 in that regard. Alternative 5 would reduce the amount of bottom trawling that occurs, and thus would cause some decline in the amount of prey exposed by trawls and eaten by scavenging benthic organisms. No negative impacts attributable to the exposure of prey have been observed under Alternative 1, as evidenced by the lack of increase in benthic scavenger populations. Alternative 5 would provide further protection from this occurring.

Discards under Alternative 5 would decline by about 3 percent in the BSAI and 4 percent in the GOA in 2005 relative to Alternative 1. These are very small changes relative to Alternative 1 and minimal changes in energy redirection, scavengers, or water quality would be anticipated from directed catch and discard observations. However, the unmeasured energy redirection from trawls exposing prey that are then eaten by scavenging benthic organisms would be reduced relative to Alternative 1, thus Alternative 5 receives a +1 because it reduces this energy redirection relative to Alternative 1.

Alternative 6.1

Alternative 6.1 would not change total observed catch amounts appreciably from Alternative 1 and thus does not provide any further protection to natural ecosystem energy flow paths and amounts relative to Alternative 1 in that regard. For this reason Alternative 6.1 was given a score of +0 for this metric.

Discards under Alternative 6.1 would increase by a large amount (40 percent) in the BSAI and decrease by 3 percent in the GOA in 2005 relative to Alternative 1. The large change in the BSAI is due to removing the regulations on improved retention and utilization. However, Alternative 6.1 proposes that fishermen optimize catch of directed target species and minimize discards without the benefit of the improved retention regulations. The actual level of discards that would be realized under Alternative 6.1 cannot be predicted quantitatively: if effective, then presumably discards would be lower than projected, but if ineffective, up to a 40 percent increase in discards would be seen relative to Alternative 1. Although the absolute level of this 40 percent increase in discards is likely to be less than the levels seen before improved retention would be put into place (in which negative impacts would not be observed), it would be a step backwards in achieving the ecosystem policy objective of minimizing waste and discards and is given a -2 score in that regard.

Alternative 6.2

Alternative 6.2 would increase total catch biomass by 16 percent relative to Alternative 1. Catch would be a very small proportion of total ecosystem biomass under Alternative 1, and Alternative 6.2 would likely not change that proportion. However, the change is a rather large negative change relative to Alternative 6.2, which is given a score of -2.

Total discards would increase under Alternative 6.2 by 26 percent, mainly due to increased catch levels. Improved retention regulations would still be in place so the estimated discard level would not be as high as Alternative 6.1. Although the discard levels are possibly of the same magnitude as those observed before the improved retention regulations would be put in place (in which negative impacts would not be observed), it would be a step backward in achieving the ecosystem policy objective of minimizing waste and discards, thus it is given a -2 score in that regard.

4.9.2.3 Effects on Biological Diversity

Fishing can alter different measures of diversity. Species level diversity, or the number of species, can be altered if fishing removes a species from the system. Fishing can alter functional or trophic diversity if it selectively removes a trophic guild member and changes the way biomass is distributed within a trophic guild. Fishing can alter genetic level diversity by selectively removing faster growing fish or removing spawning aggregrations that might have different genetic characteristics than other spawning aggregations. Large, old fishes may be more heterozygous (i.e., have more genetic differences or diversity) and some stock structures may have a genetic component (see review in Jennings and Kaiser 1998), thus one would expect a decline in genetic diversity due to heavy exploitation.

Alternative 1

Localized extinctions due to fishing are rare but some evidence exists that this may have occurred to some skate species in areas of the North Atlantic (see review in Greenstreet and Rogers 2000). These extinctions could be thought of as a decrease in species level diversity or the actual number of species in an area. Elasmobranchs such as shark, skate, and ray species are vulnerable to fishing removals and direct impacts to those species are covered in Section 4.5. Species level diversity changes have not been assessed in a quantitative fashion under the current regime. No fishing induced extinctions have been documented in the last 30 years or so. Taxonomic work on some fish species (e.g., skates) is ongoing and minimal survey and systematic work is being done on other ecosystem components, such as benthic invertebrates, that could be impacted by fishing activities. Until some of these survey and taxonomic problems are resolved, it is not possible to fully assess the impacts of Alternative 1 on species level diversity. However, given the sensitive nature of some species considered (i.e., long-lived or low-reproductive potential species, such as skates, sharks, and grenadiers), and the evidence of extinction of related species in the Atlantic, suggests that this could be a conditionally significant adverse impact on the environment under Alternative 1.

Studies of other more heavily fished systems, such as the North Sea, Georges Bank, or Gulf of Thailand have shown declines in diversity (Hall 1999a, Jennings and Reynolds 2000) related to fishing, and the diversity declines were due to direct mortality of target species. Biomass diversity and evenness for trophic guilds was investigated by Livingston et al. (1999) in the eastern Bering Sea in the current regime (Section 3.9). There appeared to be no evidence that groundfish fisheries caused declines in trophic guild diversity for the groups. For example, the biomass of diversity in the pelagic fish consumer guild was close to 1 from 1979 to 1993, a reflection of the dominance of pollock in the biomass of that group. Diversity tended to decline when pollock biomass increased due to large year-class production. Other groups, such as the benthic infauna consumer guild and the crab and fish consumer guild, had higher species biomass diversity than the pelagic fish consumer guild. Guild diversity changes were again seen when a dominant member changed in abundance. The abundance changes of those species were mostly related to recruitment changes and not to fishing. There appeared to be no fishing-induced changes in functional (trophic) diversity under Alternative 1. Functional (trophic) diversity indicators using forecasts of groundfish biomass under Alternative 1 from 2001 to 2005 indicate an 8 percent decline would occur in the diversity of groundfish biomass in the BSAI and a 3 percent increase would occur in groundfish biomass diversity in the GOA. The projected decrease in the BSAI is primarily due to the increased dominance in pollock biomass in that region while the GOA diversity change is smaller and not linked to a particular species. Thus, there appears to be no fishing-induced changes in functional diversity. This was considered to be an nonsignificant effect on the status quo environment.

Evidence so far in highly fished areas such as the North Sea suggests that there is little evidence of genetically induced change in selection for body length in cod after 40 years of exploitation (Law and Rowell 1993 cited in Jennings and Kaiser 1998). Genetic diversity has not been assessed under Alternative 1, but heavy exploitation of certain spawning aggregations can be inferred and heavier exploitation on older, more heterozygous individuals would have the tendency to reduce genetic diversity in fished versus unfished systems. Thus, some change in genetic diversity has possibly occurred in the BSAI and GOA, but the magnitude of the impacts are not known. The North Sea work indicates the impacts might be minimal. Genetic assessment of pollock populations and subpopulations in the North Pacific shows some genetic differences among stocks but has not demonstrated any genetic variability across time within stocks that might indicate fishing influences (Bailey et al. 1999). This is judged to have an nonsignificant impact on the Alternative 1 environment.

Alternative 2.1

Alternative 2.1 would likely have little change in species level diversity relative to Alternative 1, except that it could potentially help reverse the trend in species decline of Steller sea lion (an assessment of that possibility is contained in Section 4.2). It is given a score of +1 for that reason.

Trophic guild diversity of the guilds that pollock, cod, and Atka mackerel belong to would decline as these species increase their dominance in those guilds. Overall biomass diversity of the groundfish complex indicates a 4 percent decline would occur compared to Alternative 1 in the BSAI and a 2 percent increase for the GOA. These are small changes relative to Alternative 1 and likely would not change functional relationships among species (e.g., +0).

Genetic diversity could increase under Alternative 2.1 if older, more heterozygous individuals were left in the populations of cod, pollock, and Atka mackerel. Also, protection of spawning aggregations of these species under Alternative 2.1 would tend to provide increased protection of genetic diversity over Alternative 1, which might be due to differences among spawning subgroups. For this reason, Alternative 2.2 scores a +1 for this metric.

Alternative 2.2

Alternative 2.2 would likely have little change in species level diversity relative to Alternative 1, except that it could potentially reverse the trend in species decline of Steller sea lion. It is thus given a score of +1 for providing additional protection to species level diversity relative to Alternative 1.

Trophic guild diversity of the guilds that pollock, cod, and Atka mackerel belong to would decline as these species would increase their dominance in those guilds. Overall biomass diversity of the groundfish complex would decline 13 percent from Alternative 1 in the BSAI and increase 3 percent for the GOA. The change in the GOA is small relative to Alternative 1 and likely would not change functional relationships among species. The decline in biomass diversity in the BSAI is mainly due to the increase in pollock and is of the same order as changes seen when large pollock year-classes move through the system and the same as under Alternative 1. Understanding of how this dominance might affect trophic guild members that might compete for prey with pollock is still not completely understood. Alternative 2.2 would be neutral (e.g., +0) with respect to influencing trophic diversity above levels observed in natural systems.

Genetic diversity could increase under Alternative 2.2 if older, more heterozygous individuals were left in the populations of cod, pollock, and Atka mackerel. Also, protection of spawning aggregations of these species under Alternative 2.2 would also tend to increase protection over Alternative 1 of genetic diversity that might be due to differences among spawning subgroups. Thus, Alternative 2.2 is given a rank of +1 with regard to protecting genetic diversity relative to status quo.

Alternative 3

Alternative 3 would provide increased protection to target species with regard to potential for overfishing. Therefore, at the species level, it ranks higher than Alternative 1 with regard to protection of species diversity. Because these policies are applied to many target species, Alternative 3 is given a rank of +2 relative to Alternative 1.

Trophic level of the total groundfish biomass shows virtually no change from Alternative 1 level in 2005. This is an indication that functional (trophic) species composition of the groundfish community would not change appreciably from Alternative 1. Increased energy flow at higher trophic levels that would increase the food chain length and increase the life span of organisms (both of which would occur to some extent through the shift in long-term equilibrium age structure toward older fish) would be indicators of a less stressed, more mature ecosystem (Odum 1985). However, the 3 percent increase in pollock (an r-selected species) under Alternative 3 relative to Alternative 1 would indicate a slight shift toward a faster-growing, less mature system. The magnitude of change relative to changes observed due to environmentally driven changes in recruitment would suggest that there would not likely be a large ecosystem impact in this regard from Alternative 3. It thus scores a +0 relative to Alternative 1 with respect to protection of functional diversity.

Genetic diversity would be further protected under Alternative 3 relative to Alternative 1 through its policy of closing a certain proportion of spawning areas to fishing, which would tend to protect spawning subgroups and partly protect larger, more heterozygous individuals. For this reason, we gave Alternative 3 a +1 for this metric.

Alternatives 4.1 and 4.2

Alternatives 4.1 and 4.2 would potentially provide increased protection of species diversity over Alternative 1 by protecting many non-target species, such as skates, that could be vulnerable to unmeasured but high exploitation rates. Alternatives 4.1 and 4.2 rank +2 relative to Alternative 1 with respect to providing extra protection for species diversity.

Trophic guild diversity would decline somewhat relative to Alternative 1 for the pollock trophic guild due to the increase in pollock biomass in Alternatives 4.1 and 4.2 in the BSAI. However, these alternatives have the potential to protect trophic guild diversity for many groups that are not measured in the indices of Table 4.9-2. Such species as skates, grenadiers, sculpins, and sharks fill many different trophic roles and belong to several trophic guilds. Alternatives 4.1 and 4.2 would provide additional protection to many of these groups, thus they received a +1 score with respect to providing additional protection to trophic guild diversity relative to Alternative 1.

Squid closures might provide some additional protection to genetic diversity for larger, more heterozygous or spawning subgroups of squid relative to Alternative 1 (e.g., +1).

Alternative 5

Alternative 5 could potentially provide some unknown increase in species level diversity over Alternative 1 through protection of many benthic invertebrate species that could be vulnerable to high, unmeasured levels of mortality through gear impacts (e.g., gorgonian corals). It thus ranks +2 relative to Alternative 1 with respect to protection of species diversity.

No changes in trophic guild diversity that contain dominant groundfish species would be anticipated under Alternative 5. However, Alternative 5 would provide additional protection to benthic trophic guilds that supply prey to many groundfish species. It thus would provide some additional protection relative to Alternative 1 in this regard, so it receives a score of +1.

No additional protection for genetic diversity of groundfish would be expected under Alternative 5 (e.g., +0).

Alternative 6.1

Alternative 6.1 would provide no expected changes in species level, trophic guild, or genetic diversity over Alternative 1, therefore, Alternative 6.1 receives a neutral score (e.g., +0) for all three of these metrics.

Alternative 6.2

Alternative 6.2 could induce some unknown level of decline in species diversity over Alternative 1 through increased catch levels of target species. These increased catch levels could reduce protection of endangered species that rely on those species for prey. Increased bycatch of sensitive species such as skates, grenadiers, and sharks would occur along with increased mortality of benthic invertebrates such as corals, sponges, anemones, sea pens, and sea whips. Alternative 6.2 is given a score of -2 because it would reduce protection to many species.

Little change is seen in functional diversity under Alternative 6.2 relative to Alternative 1 (e.g., +0).

Alternative 6.2 would provide less protection to genetic diversity because it would possibly increase fishing intensity on spawning aggregations and on larger, more heterozygous fish. Thus, it is given a score of -1.

4.9.3 Summary of Effects

4.9.3.1 Ecosystem-level Ecological Impacts

Three main factors were evaluated from an ecological perspective at the ecosystem level to examine the ecosystem effects of the alternatives. Indexes or measures that relate to possible changes in predator-prey relationships, energy flow and balance, and various types of diversity were used in the evaluation (Table 4.9-3). Evaluation of Alternative 1 impacts with respect to these measures does not show any large negative impacts although a few were conditionally significant adverse (spatial and temporal prey removals, introduction of nonnative species, and species diversity) due to more complete knowledge of these effects (Table 4.9-4). Each alternative is ranked with respect to whether it would provide more or less protection relative to Alternative 1 using these measures (Table 4.9-4).

Four main issues are examined under the effects on predator-prey relationship: pelagic forage availability, spatial and temporal concentration of fishery on forage, removal of top predators (fishing down the food web), and introduction of nonnative species. The biomass of pollock (a key pelagic forage species) in the groundfish biomass is expected to increase 12 percent and 47 percent in the BSAI and GOA, respectively in the short term. Thus, significant positive impacts were observed in pelagic forage availability due to the increases in pollock abundance predicted to occur from 2001 to 2005 under Alternative 1. However, the spatial and temporal concentration of fisheries had a conditionally significant adverse impact on prey availability because there was not sufficient time to evaluate the effectiveness of the present mitigation scheme for reducing fishery impacts in this regard. Fisheries in these areas have not traditionally focused on top level predators but have been more focused on mixed fish and invertebrate feeders such as pollock and cod. Thus, there has not been evidence of fishing down the food web that has been seen in some highly exploited systems. Removal of top predators was thus determined to be insignificant. Although a recent report on species introductions in Port Valdez and Prince William Sound relative to oil tankers has shown that some nonnative species introductions have occurred, possibly through introduction on vessel hulls or from vessel ballast water, no particular vessel type has been implicated. Most introductions have been in shallow water and estuarine areas. So far impacts from these introductions have not been observed in Alaskan waters, but they could potentially produce large-scale changes in predator-prey interactions and species composition and are thus judged to be a conditionally significant adverse impact.

Alternatives 2.1 and 2.2 provide some of the highest measures of increased protection with respect to predator-prey relationships because of their focus on pollock and Atka mackerel. These species are important prey, not only for Steller sea lions but to many other species as well. That is the main reason Alternatives 2.1 and 2.2 would perform well at an ecosystem level. Alternatives 4.1 and 4.2 were next in providing increased protection. These alternative would perform well because of their focus on providing increased protection to squid as an important forage. Alternatives 4.1, 4.2 and 5 also reduce spatial and temporal concentrations on forage relative to Alternative 1, would provide policies to increase management of top level predators such as sharks, and would likely reduce fishing effort so that the possibility of introducing nonnative species from fishing vessel hulls and ballast waters would be reduced.

Alternative 5 would increase Atka mackerel prey availability in the Aleutian Islands, provide increased spatial refuges from fishing without increasing fishing effort outside refuges, and provide some possible decrease in fishing effort to reduce nonnative species introductions.

Alternative 6.1 would perform well in terms of reducing spatial and temporal concentrations of fishery on forage. Alternative 6.1 reduces the race for fish, which tends to concentrate fisheries in time. Fishermen also have the opportunity to increase their search for fish outside their normal fishing areas as the race for fish is eliminated. Alternative 6.1 would not provide any additional protection to pelagic forage availability, removal of top predators, or introduction of nonnative species.
Alternative 3 would increase forage availability relative to Alternative 1. Alternative 3 reductions in total catch biomass of 10 percent or greater would reduce the possibility of nonnative species introductions. However, it received a negative score on temporal and spatial reduction of forage because it did not reduce total catch when closed areas were specified. This practice might tend to increase spatial and temporal concentrations of fisheries on forage in open areas.

Alternative 6.2 would decrease forage abundance by increasing catch of forage species, which would also tend to produce increases in spatial and temporal reduction in forage availability. Alternative 6.2 is neutral with respect to removal of top predators, but the increased effort likely to occur with increased catches would increase probabilities of introduction of nonnative species.

The main measures relating ecosystem level impacts on energy flow and balance related to the total catch level (a measure of energy removal) and total discard level (a measure of energy redirection because discards may be consumed by different species in the ecosystem than if they had not been discarded). Alternative 1 levels of energy removals in the form of catch would be only about 1 percent of the estimated total ecosystem biomass and would produce an insignificant impact on this basis. Discards are projected to decrease by about 28 percent over the next five years under Alternative 1. Discards also would be about 1 percent of the natural levels of dead organic material already going to the bottom and no scavenger population would increase related to changes in discards levels in the BSAI or GOA under Alternative 1. Thus, discards would produce no significant impact on the ecosystem under Alternative 1.

Alternatives 2.1 and 2.2 would provide additional protection over Alternative 1 with respect to energy removal and discards. Measures primarily because of their reduction in pollock and Atka mackerel catch. Pollock catch tends to dominate the total catch biomass, particularly in the eastern Bering Sea. Even though discard rates in the pollock fishery tend to be low as a proportion of catch, the discards are still a large proportion of the total discards. Policies that tend to reduce catch of pollock will also tend to reduce total discards. Alternative 3 would provide extra protection to energy removals in the system by reducing total catch biomass by 10 percent or greater. Discards would not decrease as much under Alternative 3 compared to Alternatives 2.1 and 2.2 because catch reductions would be spread over a broader spectrum of species. Both target species and nontarget species would be neutral with respect to energy redirection (discard) amounts. Although the main measure of energy redirection, total discards, would not change much under Alternative 4, it still received a positive score with respect to improvement in energy redirection over Alternative 1. The positive score is because it would reduce an unmeasured source of energy redirection: bottom prey exposed by trawls and eaten by scavenging benthic organisms. Alternative 6.1 would be neutral with respect to energy removal in the form of total catch, but it received a negative score, -2, because it would remove the improved retention and utilization requirements of groundfish that are part of Alternative 1. Alternative 6.2 received the largest negative scores, -2, on both energy removal and redirection because it would increase both catch and discards to levels 10 percent greater than those observed under Alternative 1.

Three main aspects of diversity are considered in this evaluation: species diversity (number of species), functional or trophic diversity (the diversity of biomass in a trophic grouping of species), and genetic diversity (genetic diversity within species). Although no fishing-induced extinctions have been documented in the last 30 years or so, taxonomic work on some fish species (e.g., skates) is still ongoing and little survey and systematic work is being done on other ecosystem components such as benthic invertebrates that could be impacted by fishing activities. Until some of these survey and taxonomic problems are resolved, it is not possible to fully assess the impacts of Alternative 1 on species level diversity. However, given the sensitive nature of some species considered (i.e, long-lived or low reproductive potential species such as skates, shark, and grenadiers), and the evidence of extinction of related species in the Atlantic Ocean, this could be a conditionally significant adverse impact on the environment under Alternative 1. Trophic guild diversity changes observed under Alternative 1 mostly would be related to recruitment changes of a dominant guild member and not fishing. There would appear to be no fishing-induced changes in functional diversity. Therefore, this is considered to be an insignificant impact on the environment under Alternative 1. Genetic diversity changes were not assessed for Alternative 1. Heavy exploitation of certain spawning aggregations and heavier exploitation on older, more heterozygous individuals would have the tendency to reduce genetic diversity in fished versus unfished systems. Thus, some change in genetic diversity has possibly occurred in the BSAI and GOA but the magnitude of the impacts are not known. Research on genetic diversity changes in more heavily exploited areas suggests the impacts might be minimal. Thus, this was considered an insignificant impact on the status quo environment.

Target species, non-target species, and habitat alternatives (e.g., Alternatives 3, 4.1, 4.2, and 5) would all provide much more protection by species-level diversity relative to Alternative 1 by providing additional protection to harvesting many different species. Marine mammal and seabird alternatives (2.1 and 2.2) would provide additional protection primarily to two endangered species, Steller sea lions and short-tailed albatross.

Alternative 6.1 would provide no additional protection relative to Alternative 1 with respect to species diversity. Additional protection to functional diversity would be provided mainly under the non-target species and habitat alternatives (4 and 5). These alternatives protect trophic guild diversity for many members of trophic guilds presently not measured quantitatively, such as skates and sculpins (members of the benthic fish and invertebrate feeding group), sharks (member of the pelagic fish feeding guild), and sessile benthic filter-feeding invertebrate. Genetic diversity would be further protected by alternatives that reduce fishing on spawning aggregations or fishing on larger, faster growing fish. Alternatives 2 (2.1 and 2.2) and 4 (4.1 and 4.2) all rank positively in this regard. Alternative 6.2 received negative scores on both species diversity and genetic diversity.

Overall, most alternatives scored either neutral (socioeconomic Alternative 6.1) or positive with respect to providing additional protection to the ecosystem based on these ecosystem-level ecological measures. Alternatives 2.1, 2.2 and 4.2 had many high positive ranks, but Alternative 4.1 also had many positive scores. These latter alternatives performed better than Alternatives 2.1 and 2.2 with respect to diversity. Alternative 6.2 was the only alternative to receive mostly negative scores. Each other alternative targeted a certain group of species in diversity protection. Best protection of diversity would likely result from using a mixture of alternatives. No alternative obtained a dominance of the highest possible score of two. Achieving the highest ecosystem-level protection may involve combining policy objectives of a variety of alternatives.

4.9.3.2 Ecosystem-Based Management Objectives

Analysis of the alternatives with respect to how well they would meet the objectives of ecosystem-based management provides another means of evaluating ecosystem-level performance. The NRC report, *Sustaining Marine Fisheries* (NRC 1999), recommended improvements in eight categories of ecosystem-based management in order to achieve sustainable fisheries. These recommendations are to (1) adopt conservative harvest levels for single-species fisheries, (2) incorporate ecosystem considerations into fishery management decisions, (3) adopt a precautionary approach to deal with uncertainty, (4) reduce excess fishing capacity and assign fishing rights, (5) establish marine protected areas as a buffer for uncertainty, (6) include bycatch mortality in TAC accounting, (7) develop institutions to achieve goals, and (8) conduct more research on structure and function of marine ecosystems. The status quo ecosystem-based fishery management regime is reviewed and each alternative is evaluated and compared to Alternative 1 (Tables 4.9-5 and 4.9-6). Detailed information on each alternative is found in the individual alternative impacts sections. However, this section summarizes in a broad sense how each alternative performs with respect to these ecosystem-based management goals.

Alternative 1 would make many improvements in meeting each ecosystem-based management objective. Conservative single-species management is the cornerstone of ecosystem-based management in the BSAI and GOA. No fish stocks have been deemed overfished, the intended catch is well below the absolute catch limit, harvest rate specifications are more conservative for some management tiers when less information is available, harvest rates are reduced at lower than average stock size levels to allow rebuilding, OY limits add additional precaution, and observer catch monitoring allows catches to stay within specified levels. However, additional information on target and non-target species could provide substantial improvements to conservative single-species management. Better knowledge of spatial/temporal distribution of stocks could help prevent localized stock depletion. More information on species-specific fish stock abundance and life history characteristics would help define overfishing levels for stocks for which those levels have not yet been defined. Incorporating uncertainty into assessment procedures would also lead to more conservative harvest levels. Some alternatives offer improvements to conservative single-species harvest levels. Alternatives 2.1 and 2.2 offer increased conservatism in the harvest of a few species (pollock, cod, and Atka mackerel). Alternative 5 also offers more conservatism to the harvest of some species (flatfish and Atka mackerel). Alternatives 3, 4.1 and 4.2 add additional conservatism to broad groups of species, while Alternative 6.1 would maintain the status quo in this regard. Alternative 6.2 offers a less conservative single-species management.

Table 4.9-5 Scoring System for Ranking How Well Each Alternative Achieves Ecosystem-Based Management Goals

Goal	Score				
	-2	-1	+0	+1	+2
Conservative single species harvest levels	Less conservative harvest levels for many species	Less conservative harvest levels for some species	Continue present policy	Adds more conservatism to harvest levels of some species	Adds more conservatism to harvest levels of many species
Incorporate ecosystem considerations into fishery management decisions	Consideration of ecosystem factors in much fewer management decisions	Consideration of ecosystem factors in fewer management decisions	Present consideration of ecosystem factors	Consideration of ecosystem factors in more decisions	Consideration of ecosystem factors in many more decisions
Precautionary approach to deal with uncertainty	Less precaution to many more species/decisions	Less precaution to some more species/decisions	Present level of precaution	Adds more precaution to some more species/decisions	Adds more precaution to many more species/decisions
Reduce excess fishing capacity and assign fishing rights	Creates large excess capacity or loss of fishing rights in many fisheries	Creates some excess capacity or loss of fishing rights in some fisheries	Present level of fishing capacity control and assignment of fishing rights	More control of fishing capacity and greater rights assignment to some fisheries	More control of fishing capacity and rights assignment to many fisheries
Establish marine protected areas	Much less area protected	Some less area protected	Present level of marine protected areas	Some more marine protected areas	Many more marine protected areas
Include bycatch mortality into TAC accounting	Ignore bycatch mortality in TAC accounting for many species	Ignore bycatch mortality in TAC accounting in some species	Present level of inclusion of bycatch mortality in TAC accounting	Increased level of of bycatch mortality in TAC accounting for some species	Increased level of bycatch mortality in TAC accounting for many species
Develop institutions to achieve goals	Removal of institutions to achieve many goals	Removal of institutions to achieve some goals	Present institutional structure	Creation of new/revised institutions to achieve goals	Creation of new/revised institutions to achieve many goals
Conduct more research on structure and function of marine ecosystems	Less research on many components	Less research on some components	Existing level and direction of research	More research on some components	More research on many components

Notes: TAC – total allowable catch

Table 4.9-6 Scores for Each Alternatives Relative Level of Achieving Ecosystem-Based Management Goals[a]

Ecosystem-Based Management Goal	Alternative 1	Alternative 2: 2.1	Alternative 2: 2.2	3	4.1 and 4.2	5	6.1	6.2
Conservative single-species harvest levels	0	1	1	2	2	1	0	-2
Incorporate ecosystem considerations into fishery management	0	1	1	0	0	1	0	-1
Precautionary approach to deal with uncertainty	0	1	1	2	2	2	1	-2
Reduce excess fishing capacity and assign fishing rights	0	-1	-2	-1	-1	0	2	1
Establish marine protected areas	0	2	0	2	1	2	0	0
Include bycatch mortality into TAC accounting	0	0	0	0	2	0	2	0
Develop institutions to achieve goals	0	0	0	0	0	0	2	0
Conduct more research on structure and function of marine ecosystems	0	1	0	1	2	2	1	0

Notes: [a]The index values contained in this table only contain ordinal information and can only be used to make ordinal comparisons. For example, an index value of +2 is better than a value of +1, but a +2 is not necessarily twice as good or twice as large as a +1. Therefore, it is not possible to obtain meaningful summary information by performing numerical operations (e.g., add or subtract index values or calculate their ratios) using two or more of the index values.
TAC – total allowable catch

Incorporating ecosystem considerations into fishery management means taking account of known and probable goods and services of marine ecosystems that are potentially jeopardized by fishing. These considerations include provision of prey and other habitat aspects to ecosystem components and protecting energy flow and redirection. The status quo regime has taken into account marine mammal critical habitat by reducing mammal prey harvest levels inside these areas. Forage fish species have been protected by provisions that prevent new fisheries starting on those species. Habitat protection of various ecosystem components such as sea lions, herring, and crab has been provided by time and area closures. Fishery discards have been reduced substantially by the improved retention and utilization requirements and prevent energy redirection in these ecosystems. However, better understanding prey requirements of protected species and habitat requirements of fish could lead to improved ecosystem-based management. Alternatives 2.1 and 2.2 would provide additional protection to sea lion prey. Alternative 5 would further protect benthic fish habitat and particularly gorgonian coral areas. Alternatives 4.1 and 4.2 would provide extra protection to squid as prey and many other ecosystem components. In rights-based management proposed under Alternative 6.1, users would be held accountable for resources they use and the costs, including environmental costs, they impose. Thus, Alternative 6.1 would internalize ecosystem considerations rather than considering them as an externality as Alternative 1 does. Alternative 6.2 would provide less protection to prey and energy removal and redirection.

The precautionary approach to deal with uncertainty means providing a way to take into account the incomplete understanding of and ability to predict fish population dynamics, interactions among species, effects of environmental factors on fish population, and effects of human actions. A variety of steps would be taken in the BSAI and GOA Groundfish FMPs (Alternative 1) to provide additional precaution in the face of uncertainty. The most visible means is the tier system of setting ABCs of fish based on information availability of population dynamics parameters. As mentioned above in ecosystem considerations, forage fish protection and protection of sea lion critical habitat are other examples of precaution in the face of uncertainty. Virtually all the alternatives provide additional ways to deal with uncertainty to provide improvements over the status quo regime. Alternatives 2.1 and 2.2 would provide further precaution in dealing with uncertainty about effects of fishing removals of Steller sea lion prey. Alternative 3 would provide additional precaution by explicit consideration of uncertainty in survey estimates of many groundfish species. Alternatives 4.1 and 4.2 would provide additional precaution by imposing management rules on a large group of non-target fish species for which complete information about abundance or species-specific catch rates is lacking. Alternative 5 would provide additional precaution about the uncertainty of effects of fishing on benthic habitat and corals by setting areas aside for protection and switching to alternative gear types. Additional precaution under Alternative 6.1 would impose rights-based management. Alternative 6.1 not only would provide additional precaution by its system of holding users accountable and imposing monitoring to ensure that accountability, it would also provide a system with more rapid response to observed changes than the present system, which relies on the time-consuming process of regulatory amendments. Alternative 6.2 would remove precaution by advocating fishing rates for some species up to the overfishing level.

Reducing excess fishing capacity and assignment of fishing rights is recognized as a primary means of reducing pressure to overfished stocks. The status quo regime has imposed a moratorium on new vessel entry into the federally managed groundfish and crab fisheries. A license limitation program for these vessels was implemented on January 1, 2000, which replaces this moratorium. Sablefish and halibut IFQ programs have reduced overcapacity in those fisheries, as has the recently implemented American Fisheries Act, which reduces harvesting capacity in the BSAI pollock fishery. These programs could be more broadly applied than in the present fishery management regime. The only alternative that would provide additional control of excess capacity and assignment of fishing rights is Alternative 6, which explicitly proposes to extend assignment of fishing rights to all target groundfish and prohibited species category fisheries. The other alternatives, which propose to reduce TAC in fisheries, would result in an increase in excess fishery capacity, at least in the short term. Alternative 6.2 might reduce excess fishery capacity in the short term through its policy of TAC increases.

Establishment of marine protected areas, where fishing is prohibited, is one means of protecting and rebuilding ecosystems and populations of marine species. As such, it should be considered as one of the tools of ecosystem-based management and not the sole tool. Areas of the Bering Sea that are closed to year-round trawling encompass 25 percent of the Bering Sea shelf areas where most fishing presently occurs and GOA closed areas now encompass about 10 percent of the trawlable shelf area. Evaluation of the areas now protected and development of strategic goals for habitat protection by area need to be performed to make improvements beyond the status quo regime. The alternatives offer some suggestions for more optimal habitat protection beyond the status quo regime. Alternative 2.1 proposes much extended marine protected areas, where fishing for pollock, cod, and Atka mackerel would be prohibited, while Alternative 2.2 proposes no new protected areas. Alternative 3 would close 20 percent of all management areas year-round fishing, thus providing, a much greater amount of protected area relative to Alternative 1. Alternative 5 would also close large areas to bottom trawling in order to provide additional protection to benthic habitat and close some areas to all fishing in order to protect gorgonian corals. Alternatives 4.1 and 4.2 would establish additional areas for protection in the form of squid protection areas along the outer shelf of the BSAI. Alternatives 6.1 and 6.2 would provide no additional marine protected areas.

Explicit accounting of bycatch and discards in the assessment of fishing mortality on species is an important ecosystem-based management action. Methods and gears to reduce bycatch should also be encouraged. The status quo management regime has instituted many controls and accounting systems for bycatch and discards. Bycatch limits have been developed for prohibited species categories and groundfish fisheries are stopped when these limits have been reached. Target species discards are explicitly counted and added into landed catches in assessment of fishing mortality for groundfish. Improved retention and utilization regulations have also reduced the amount of pollock and cod that are discarded, and flatfish retention will be mandated in 2003. Only two alternatives have the potential to provide additional inclusion of bycatch mortality in TAC accounting. Alternative 4.1 and 4.2 would add TAC setting and associated inclusion of bycatch into TAC setting for species that are presently not targets of groundfish fisheries. Alternative 6.1, by virtue of its rights-based management that holds users accountable for the resources they use and mandates a monitoring system to account for that use, would also provide additional accounting of bycatch mortality in TAC setting.

Developing institutions to achieve ecosystem-based management goals is also important. Institutions should incorporate diverse views and institutional structures should be developed that promote reduction of excess capacity, sustainable catches of target species, expansion of fishery management to include all sources of environmental degradation, consideration of ecosystem effects of fishing, effective monitoring and enforcement, and collection of important data. The status quo regime is characterized by the Council's structure and associated groups. The Council has diverse representation and numerous committees that represent natural resource agencies, industry, fishing communities, environmental organizations, recreational fishermen, and academia. Alternative 6.1 is the only alternative that would add organizational structure through its implementation of rights-based management.

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Research on the structure and function of ecosystems, long-term research and monitoring, a variety of modeling efforts, biological effects of fishing, effectiveness of MPAs, and effectiveness of various forms of rights-based management would all be required to effectively implement ecosystem-based management. Although research is ongoing with respect to all of these categories, implementing the additional protection proposed in many of the alternatives would require much more additional research. Setting appropriate boundaries for Steller sea lion conservation would require additional research on Steller sea lion foraging needs and target species seasonal movements. Target species require more accurate determination of critical life history parameters and survey estimates. Non-target species need much more work on taxonomy and life history characteristics and distribution. Implementation of optimal areas for fish habitat protection would require long-term research on the effectiveness of MPAs. Finally, implementing rights-based management would require additional information on the effects and effectiveness of various forms of rights-based management.

Overall, the alternatives would perform positively with respect to providing additional ways to move toward ecosystem-based management. Alternative 6.1 had many high scores and non-target species and habitat also several high positive scores. Alternative 2.1 and Alternative 3 follow. Alternative 2.2 would not perform much above the status quo because it does not explicitly establish marine protected areas and would cause the largest short-term increases in excess capacity. As mentioned earlier, some alternatives have competing objectives (e.g, TAC reduction and excess capacity reductions), and some alternatives perform better on particular objective than others. Alternative 6.2 receives several negative scores. Ultimately, achieving an ecosystem-based management regime that best meets all eight goals examined here will be met through a combination of features of each individual alternative, which were designed to delineate and sharply define specific issues. Ecosystem-based management is a regime that involves a combination of a broad set of issues from single-species management, to ecosystem considerations, and finally to economic concerns and the role of humans in these ecosystems.